WONDER BOOK
OF THE
WORLD'S PROGRESS

VOL. III

EARLY SCIENCE
THE GROWTH OF KNOWLEDGE

STATUE OF RAMSES THE GREAT

WONDER BOOK
OF THE
WORLD'S PROGRESS

By

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IN TEN VOLUMES

Illustrated

•

VOLUME III

Early Science
The Growth of Knowledge

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EARLY SCIENCE
THE GROWTH OF KNOWLEDGE

I

PREHISTORIC SCIENCE

TO speak of a prehistoric science may seem like a contradiction of terms. The word prehistoric seems to imply barbarism, while science, clearly enough, seems the outgrowth of civilization; but rightly considered, there is no contradiction. For, on the one hand, man had ceased to be a barbarian long before the beginning of what we call the historical period; and, on the other hand, science, of a kind, is no less a precursor and a cause of civilization than it is a consequent.

Science, as the word is commonly used, implies: first, the gathering of knowledge through observation; second, the classification of such knowledge, and through this classification, the elaboration of general ideas or principles.

In the familiar definition of Herbert Spencer, science is organized knowledge.

Now it is patent enough, at first glance, that the veriest savage must have been an observer of the phenomena of nature. He must also have been a classifier of his observations—an organizer of knowledge. The two methods are too closely linked together to be dissevered. To observe outside phenomena is not more inherent in the nature of the mind than to draw inferences from these phenomena. A deer passing through the forest scents the ground and detects a certain odor. A sequence of ideas is generated in the mind of the deer. Nothing in the deer's experience can produce

that odor but a wolf; therefore the scientific inference is drawn that wolves have passed that way.

But it is a part of the deer's scientific knowledge, based on previous experience, individual and racial, that wolves are dangerous beasts, and so, combining direct observation in the present with the application of a general principle based on past experience, the deer reaches the very logical conclusion that it may wisely turn about and run in another direction.

All this implies, essentially, a comprehension and use of scientific principles; and, strange as it seems to speak of a deer as possessing scientific knowledge, there is really no absurdity in the statement. The deer does possess scientific knowledge; knowledge differing in degree only, not in kind, from the knowledge of a Newton.

Nor is the animal, within the range of its intelligence, less logical, less scientific in the application of that knowledge, than is the man. The animal that could not make accurate scientific observations of its surroundings, and deduce accurate scientific conclusions from them, would soon pay the penalty of its lack of logic.

What is true of man's precursors in the animal scale is, of course, true in a wider and fuller sense of man himself at the very lowest stage of his development. Ages before the time which the limitations of our knowledge force us to speak of as the dawn of history, man had reached a high stage of development. As a social being, he had developed all the elements of a primitive civilization.

Even in the Stone Age, man was a mechanic of marvelous skill, as any one of today may satisfy himself by attempting to duplicate such an implement as a chipped arrow-head. And a barbarian who could

fashion an ax or a knife of bronze had certainly gone far in his knowledge of scientific principles and their practical application. The practical application was, doubtless, the only thought that our primitive ancestor had in mind. Yet, in spite of himself, he knew certain rudimentary principles of science, even tho he did not formulate them.

Let us inquire what some of these principles are

Primitive man must have conceived that the earth is flat and of limitless extent. By this it is not meant to imply that he had a distinct conception of infinity; but, for that matter, it cannot be said that any one to-day has a conception of infinity that could be called definite.

But, reasoning from experience and the reports of travelers, there was nothing to suggest to early man the limit of the earth He did, indeed, find in his wanderings, that changed climatic conditions barred him from farther progress; but beyond the farthest reaches of his migrations, the seemingly flat land-surfaces and water-surfaces stretched away unbroken and, to all appearances, without end. It would require a reach of the philosophical imagination to conceive a limit to the earth.

Primitive man must, from a very early period, have observed that the sun gives heat and light, and that the moon and stars seem to give light only and no heat. It required but a slight extension of this observation to note that the changing phases of the seasons were associated with the seeming approach and recession of the sun.

This observation, however, could not have been made until man had migrated from the tropical regions, and had reached a stage of mechanical development ena-

bling him to live in subtropical or temperate zones. Even then it is conceivable that a long period must have elapsed before a direct causal relation was felt to exist between the shifting of the sun and the shifting of the seasons; because, as every one knows, the periods of greatest heat in summer and greatest cold in winter usually come some weeks after the time of the solstices. Yet, the fact that these extremes of temperature are associated in some way with the change of the sun's place in the heavens must, in time, have impressed itself upon even a rudimentary intelligence.

It is hardly necessary to add that this is not meant to imply any definite knowledge of the real meaning of the seeming oscillations of the sun. We shall see that, even at a relatively late period, the vaguest notions were still in vogue as to the cause of the sun's changes of position

It required a relatively high development of the observing faculties, yet a development which man must have attained ages before the historical period, to note that the moon has a secondary motion, which leads it to shift its relative position in the heavens, as regards the stars; that the stars themselves, on the other hand, keep a fixed relation as regards one another, with the notable exception of two or three of the most brilliant members of the galaxy, the latter being the bodies which came to be known finally as planets, or wandering stars.

The wandering propensities of such brilliant bodies as Jupiter and Venus cannot well have escaped detection. We may safely assume, however, that these anomalous motions of the moon and planets found no explanation that could be called scientific until a relatively late period.

Turning from the heavens to the earth, and ignoring

such primitive observations as that of the distinction between land and water, we may note that there was one great scientific law which must have forced itself upon the attention of primitive man. This is the law of universal terrestrial gravitation.

The word gravitation suggests the name of Newton, and it may excite surprize to hear a knowledge of gravitation ascribed to men who preceded that philosopher by, say, twenty-five or fifty thousand years Yet the slightest consideration of the facts will make it clear that the great central law that all heavy bodies fall directly toward the earth, cannot have escaped the attention of the most primitive intelligence. The arboreal habits of our primitive ancestors gave opportunities for constant observation of the practicalities of this law.

Other physical facts going to make up an elementary science of mechanics, that were demonstratively known to prehistoric man, were such as these: the rigidity of solids and the mobility of liquids; the fact that changes of temperature transform solids to liquids and *vice versa*—that heat, for example, melts copper and even iron, and that cold congeals water; and the fact that friction, as illustrated in the rubbing together of two sticks, may produce heat enough to cause a fire.

The rationale of this last experiment did not receive an explanation until about the beginning of the nineteenth century of our own era. But the experimental fact was so well known to prehistoric man that he employed this method, as various savage tribes employ it to this day, for the altogether practical purpose of making a fire; just as he employed his practical knowledge of the mutability of solids and liquids in smelting ores, in alloying copper with tin to make bronze, and in casting this alloy in molds to make various implements.

Here, then, were the germs of an elementary science of physics

In the field of what we now speak of as biological knowledge, primitive man had obviously the widest opportunity for practical observation. We can hardly doubt that man attained, at an early day, to that conception of identity and of difference which Plato places at the head of his metaphysical system. It is precisely such general ideas as these that were man's earliest inductions from observation, and hence that came to seem the most universal and "innate" ideas of his mentality.

It is quite inconceivable, for example, that even the most rudimentary intelligence that could be called human could fail to discriminate between living things and, let us say, the rocks of the earth. The most primitive intelligence, then, must have made a tacit classification of the natural objects about it into the grand divisions of animate and inanimate nature.

Doubtless the nascent scientist may have imagined life animating many bodies that we should call inanimate—such as the sun, wandering planets, the winds, and lightning; and, on the other hand, he may quite likely have relegated such objects as trees to the ranks of the non-living; but that he recognized a fundamental distinction between, let us say, a wolf and a granite boulder we cannot well doubt.

A step beyond this—a step, however, that may have required centuries or millenniums in the taking—must have carried man to a plane of intelligence from which a primitive Aristotle or Linnæus was enabled to note differences and resemblances connoting such groups of things as fishes, birds, and furry beasts.

This conception, to be sure, is an abstraction of a relatively high order. We know that there are savage

races today whose language contains no word for such an abstraction as bird or tree. We are bound to believe, then, that there were long ages of human progress during which the highest man had attained no such stage of abstraction; but, on the other hand, it is equally little in question that this degree of mental development had been attained long before the opening of our historical period.

The primeval man, then, whose scientific knowledge we are attempting to predicate, had become, through his conception of fishes, birds, and hairy animals as separate classes, a scientific zoologist of relatively high attainments.

In the practical field of medical knowledge, a certain stage of development must have been reached at a very early day. Even animals pick and choose among the vegetables about them, and at times seek out certain herbs quite different from their ordinary food, practising a sort of instinctive therapeutics. The cat's fondness for catnip is a case in point. The most primitive man, then, must have inherited a racial or instinctive knowledge of the medicinal effects of certain herbs; in particular he must have had such elementary knowledge of toxicology as would enable him to avoid eating certain poisonous berries.

Coupled with this knowledge of things dangerous to the human system, there must have grown up, at a very early day, a belief in the remedial character of various vegetables as agents to combat disease.

Here, of course, was a rudimentary therapeutics, a crude principle of an empirical art of medicine.

As just suggested, the lower order of animals have an instinctive knowledge that enables them to seek out remedial herbs (tho we probably exaggerate the extent

of this instinctive knowledge); and if this be true, man must have inherited from his prehuman ancestors this instinct along with the others. That he extended this knowledge through observation and practise, and came early to make extensive use of drugs in the treatment of disease, is placed beyond cavil through the observation of the various existing barbaric tribes, nearly all of whom practise elaborate systems of therapeutics.

All this, however, implies an appreciation of the fact that man is subject to "natural" diseases, and that if these diseases are not combated, death may result. But it should be understood that the earliest man probably had no such conception as this. Throughout all the ages of early development, what we call "natural" disease and "natural" death meant the onslaught of a tangible enemy It is probable, however, that the idea of natural death, as we now conceive it, came to primitive man as a relatively late scientific induction. This thought seems almost startling, so axiomatic has the conception "man is mortal" come to appear. Yet a study of the ideas of existing savages, combined with our knowledge of the point of view from which historical peoples regard disease, make it more probable that the primitive conception of human life did not include the idea of necessary death.

We are told that the Australian savage who falls from a tree and breaks his neck is not regarded as having met a natural death, but as having been the victim of the magical practises of the "medicine-man" of some neighboring tribe.

Similarly, the Egyptian and the Babylonian of the early historical period conceived illness as being almost invariably the result of the machinations of an enemy. One need but recall the superstitious observances of the

Middle Ages, and the yet more recent belief in witchcraft, to realize how generally disease has been personified as a malicious agent invoked by an unfriendly mind.

Indeed, the phraseology of our present-day speech is still reminiscent of this; as when, for example, we speak of an "attack of fever," and the like.

When, following out this idea, we picture to ourselves the conditions under which primitive man lived, it will be evident at once how relatively infrequent must have been his observation of what we usually term natural death. His world was a world of strife; he lived by the chase; he saw animals kill one another; he witnessed the death of his own fellows at the hands of enemies. Naturally enough, then, when a member of his family was "struck down" by invisible agents, he ascribed this death also to violence, even tho the offensive agent was concealed.

It seems a justifiable inference that the first conception primitive man would have of his own life would not include the thought of natural death, but would, conversely, connote the vague conception of endless life. Our own ancestors, a few generations removed, had not got rid of this conception, as the perpetual quest of the spring of eternal youth amply testifies. A naturalist of our own day has suggested that perhaps birds never die except by violence.

The thought, then, that man has a term of years beyond which "in the nature of things," as the saying goes, he may not live, would have dawned but gradually upon the developing intelligence of successive generations of men; and we cannot feel sure that he would fully have grasped the conception of a "natural" termination of human life until he had shaken himself free from the idea that disease is always the result of the magic prac-

tise of an enemy. It is somewhat doubtful whether this conception had been attained before the close of the prehistoric period.

Turning from the body to its mental complement, we are forced to admit that here, also, our primitive man must have made certain elementary observations that underlie such sciences as psychology, mathematics, and political economy. The elementary emotions associated with hunger and with satiety, with love and with hatred, must have forced themselves upon the earliest intelligence that reached the plane of conscious self-observation.

The capacity to count, at least to the number four or five, is within the range of even animal intelligence. Certain savages have gone scarcely farther than this; but our primeval ancestor, who was forging on toward civilization, had learned to count his fingers and toes, and to number objects about him by fives and tens in consequence, before he passed beyond the plane of numerous existing barbarians How much beyond this he had gone we need not attempt to inquire; but the relatively high development of mathematics in the early historical period suggests that primeval man had attained a not-inconsiderable knowledge of numbers.

The humdrum vocation of looking after a numerous progeny must have taught the mother the rudiments of addition and subtraction; and the elements of multiplication and division are implied in the capacity to carry on even the rudest form of barter, such as the various tribes must have practised from an early day.

As to political ideas, even the crudest tribal life was based on certain conceptions of ownership, at least of tribal ownership, and the application of the principle of likeness and difference to which we have already re-

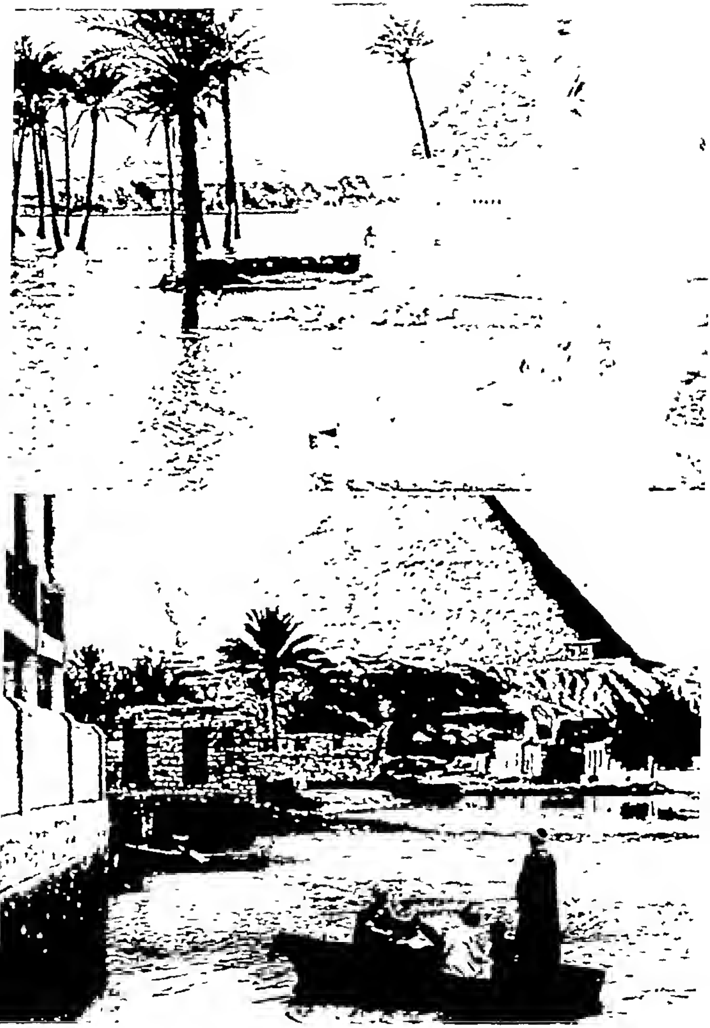
ferred. Each tribe, of course, differed in some regard from other tribes, and the recognition of these differences implied in itself a political classification

A certain tribe took possession of a particular hunting-ground, which became, for the time being, its home, and over which it came to exercise certain rights. An invasion of this territory by another tribe might lead to war, and the banding together of the members of the tribe to repel the invader implied both a recognition of communal unity and a species of prejudice in favor of that community that constituted a primitive patriotism.

But this unity of action in opposing another tribe would not prevent a certain rivalry of interest between the members of the same tribe, which would show itself more and more prominently as the tribe increased in size. The association of two or more persons implies, always, the ascendency of some and the subordination of others. Leadership and subordination are necessary correlatives of difference of physical and mental endowment, and rivalry between leaders would inevitably lead to the formation of primitive political parties

With the ultimate success and ascendency of one leader, who secures either absolute power or power modified in accordance with the advice of subordinate leaders, we have the germs of an elaborate political system—an embryo science of government.

Meanwhile, the very existence of such a community implies certain individual rights, the recognition of which is essential to communal harmony. The right of individual ownership of the various articles and implements of every-day life must be recognized, or all harmony would be at an end. Certain rules of justice—primitive laws—must, by common consent, give protection to the

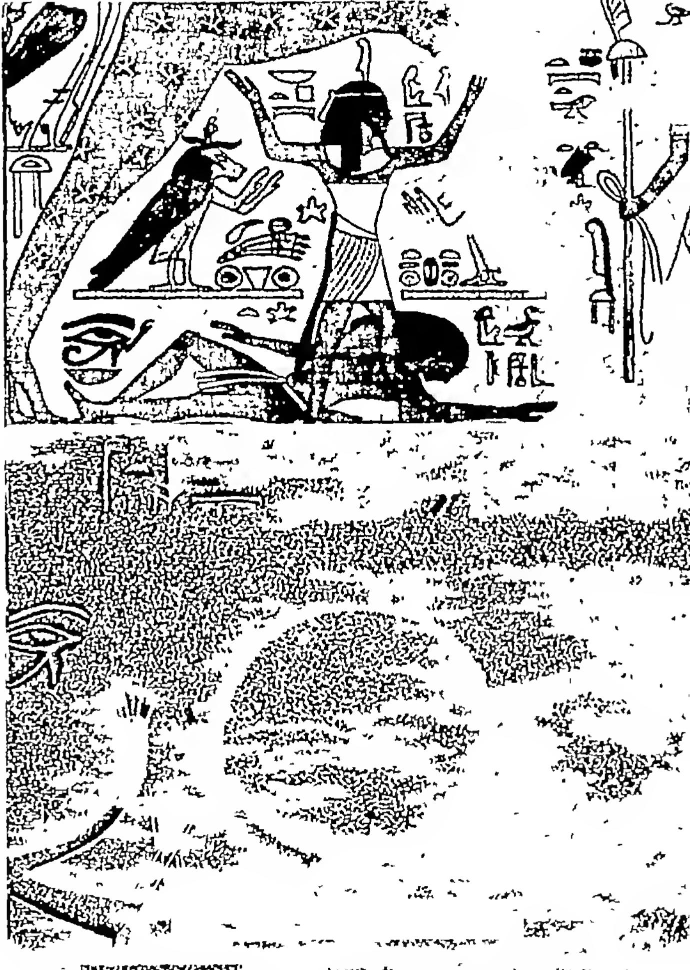


INUNDATION OF NILE, MODERN EGYPT

weakest members of the community. Here are the rudiments of a system of ethics

It may seem anomalous to speak of this primitive morality, this early recognition of the principles of right and wrong, as having any relation to science Yet, rightly considered, there is no incongruity in such a citation There cannot well be a doubt that the adoption of those broad principles of right and wrong which underlie the entire structure of modern civilization was due to scientific induction—in other words, to the belief, based on observation and experience, that the principles implied were essential to communal progress

It would appear, then, that the entire superstructure of later science had its foundation in the knowledge and practise of prehistoric man The civilization of the historical period could not have advanced as it has had there not been countless generations of culture back of it. The new principles of science could not have been evolved had there not been basic principles which ages of unconscious experiment had impressed upon the mind of our race.



DAY SEPARATED FROM NIGHT — THE SUN
PILOTED ACROSS THE SKY

II

EGYPTIAN SCIENCE

IN the previous chapter I have purposely refrained from referring to any particular tribe or race of historical man. Now, however, we are at the beginnings of national existence, and we have to consider the accomplishments of an individual race; or rather, perhaps, of two or more races that occupied successively the same geographical territory.

We are still, it must be understood, at the beginnings of history; indeed, we must first bridge over the gap from the prehistoric before we may find ourselves fairly on the line of march of historical science.

At the very outset we may well ask what constitutes the distinction between prehistoric and historic epochs —a distinction which has been constantly implied in much that we have said. The reply savors somewhat of vagueness. It is a distinction having to do, not so much with facts of human progress as with our interpretation of these facts.

When we speak of the dawn of history we must not be understood to imply that, at the period in question, there was any sudden change in the intellectual status of the human race or in the status of any individual tribe or nation of men. What we mean is that modern knowledge has penetrated the mists of the past for the period we term historical with something more of clearness and precision than it has been able to bring to bear upon yet earlier periods

New accessions of knowledge may thus shift from time to time the bounds of the so-called historical period. The clearest illustration of this is furnished by our interpretation of Egyptian history. Until recently the biblical records of the Hebrew captivity or service, together with the similar account of Josephus, furnished about all that was known of Egyptian history even of so comparatively recent a time as that of Ramses II. (fifteenth century B.C.), and from that period on there was almost a complete gap until the story was taken up by the Greek historians Herodotus and Diodorus

It is true that the king-lists of the Alexandrian historian, Manetho, were all along accessible in somewhat garbled copies But at best they seemed to supply unintelligible lists of names and dates which no one was disposed to take seriously. That they were, broadly speaking, true historical records, and most important historical records at that, was not recognized by modern scholars until fresh light had been thrown on the subject from altogether new sources.

These new sources of knowledge of ancient history demand a moment's consideration They are all-important because they have been the means of extending the historical period of Egyptian history (using the word history in the way just explained) by three or four thousand years. As just suggested, that historical period carried the scholarship of the early nineteenth century scarcely beyond the fifteenth century B.C., but today's vision extends with tolerable clearness to about the middle of the fifth millennium B.C.

This change has been brought about chiefly through study of the Egyptian hieroglyphics These hieroglyphics constitute, as we now know, a highly developed system of writing; a system that was practised for some thou-

sands of years, but which fell utterly into disuse in the later Roman period, and the knowledge of which passed absolutely from the mind of man For about two thousand years no one was able to read, with any degree of explicitness, a single character of this strange script, and the idea became prevalent that it did not constitute a real system of writing, but only a more or less barbaric system of religious symbolism

The falsity of this view was shown early in the nineteenth century when Dr Thomas Young was led, through study of the famous trilingual inscription of the Rosetta stone, to make the first successful attempt at clearing up the mysteries of the hieroglyphics

This is not the place to tell the story of his fascinating discoveries and those of his successors That story belongs to nineteenth-century science, not to the science of the Egyptians. Suffice it here that Young gained the first clue to a few of the phonetic values of the Egyptian symbols, and that the work of discovery was carried on and vastly extended by the Frenchman Champollion, a little later, with the result that the firm foundations of the modern science of Egyptology were laid.

Subsequently such students as Rosellini the Italian, Lepsius the German, and Wilkinson the Englishman, entered the field, which in due course was cultivated by De Rougé in France and Birch in England, and by such distinguished latter-day workers as Chabas, Mariette, Maspero, Amélineau, and De Morgan among the Frenchmen; Professor Petrie and Dr. Budge in England: and Brugsch Pasha and Professor Erman in Germany, not to mention a large coterie of somewhat less familiar names.

These men working, some of them in the field of practical exploration, some as students of the Egyptian

EGYPTIAN DESERT

language and writing, have restored to us a tolerably precise knowledge of the history of Egypt from the time of the first historical king, Mena, whose date is placed at about the middle of the fifth century B C We know not merely the names of most of the subsequent rulers, but something of the deeds of many of them; and, what is vastly more important, we know, thanks to the modern interpretation of the old literature, many things concerning the life of the people, and in particular concerning their highest culture, their methods of thought, and their scientific attainments, which might well have been supposed to be past finding out.

Nor has modern investigation halted with the time of the first kings; the recent explorations of such archeologists as Amélineau, De Morgan, and Petrie have brought to light numerous remains of what is now spoken of as the predynastic period—a period when the inhabitants of the Nile Valley used implements of chipped stone, when their pottery was made without the use of the potter's wheel, and when they buried their dead in curiously cramped attitudes without attempt at mummification. These aboriginal inhabitants of Egypt cannot perhaps with strict propriety be spoken of as living within the historical period, since we cannot date their relics with any accuracy. But they give us glimpses of the early stages of civilization upon which the Egyptians of the dynastic period were to advance.

It is held that the nascent civilization of these Egyptians of the Neolithic, or late Stone Age, was overthrown by the invading hosts of a more highly civilized race which probably came from the East, and which may have been of a Semitic stock The presumption is that this invading people brought with it a knowledge of the arts of war and peace developed in its old home.

The introduction of these arts served to bridge somewhat suddenly, so far as Egypt is concerned, that gap between the prehistoric and the historic stage of culture to which we have all along referred. The essential structure of that bridge, let it now be clearly understood, consisted of a single element. That element is the capacity to make written records: a knowledge of the art of writing. Clearly understood, it is this element of knowledge that forms the line bounding the historical period.

Numberless mementos are in existence that tell of the intellectual activities of prehistoric man; such mementos as flint implements, pieces of pottery, and fragments of bone, inscribed with pictures that may fairly be spoken of as works of art; but so long as no written word accompanies these records, so long as no name of king or scribe comes down to us, we feel that these records belong to the domain of archeology rather than to that of history. Yet it must be understood all along that these *two domains shade one into the other; it has already* been urged that the distinction between them is one that pertains rather to modern scholarship than to the development of civilization itself.

Bearing this distinction still in mind, and recalling that the historical period, which is to be the field of our observation throughout the rest of our studies, extends for Egypt well back into the fifth millennium B.C., let us briefly review the practical phases of that civilization to which the Egyptian had attained before the beginning of the dynastic period. Since theoretical science is everywhere linked with the mechanical arts, this survey will give us a clear comprehension of the field that lies open for the progress of science in the long stages of historical time upon which we are just entering.

We may pass over such rudimentary advances in the

direction of civilization as are implied in the use of articulate language, the application of fire to the uses of man, and the systematic making of dwellings of one sort or another, since all of these are stages of progress that were reached very early in the prehistoric period

What more directly concerns us is that a really high stage of mechanical development had been reached before the dawnings of Egyptian history proper. All manner of household utensils were employed; the potter's wheel aided in the construction of a great variety of earthen vessels; weaving had become a fine art, and weapons of bronze, including axes, spears, knives, and arrow-heads, were in constant use Animals had long been domesticated, in particular the dog, the cat, and the ox; the horse was introduced later from the East. The practical arts of agriculture were practised almost as they are at the present day in Egypt, there being, of course, the same dependence then as now upon the inundations of the Nile.

As to government, the Egyptian of the first dynasty regarded his king as a demigod to be actually deified after his death, and this point of view was not changed throughout the stages of later Egyptian history.

In point of art, marvelous advances upon the skill of the prehistoric man had been made, probably in part under Asiatic influences, and that unique style of stilted yet expressive drawing had come into vogue, which was to be remembered in after times as typically Egyptian.

More important than all else, our Egyptian of the earliest historical period was in possession of the art of writing. He had begun to make those specific records which were impossible to the man of the Stone Age, and thus he had entered fully upon the way of historical

PYRAMID OF GIZEH, CAIRO

progress which, as already pointed out, has its very foundation in written records From now on the deeds of individual kings could find specific record It began to be possible to fix the chronology of remote events with some accuracy; and with this same fixing of chronologies came the advent of true history

The period which precedes what is usually spoken of as the first dynasty in Egypt is one into which the present-day searcher is still able to see but darkly The evidence seems to suggest that an invasion of relatively cultured people from the East overthrew, and in time supplanted, the Neolithic civilization of the Nile Valley It is impossible to date this invasion accurately, but it cannot well have been later than the year 5000 B C., and it may have been a great many centuries earlier than this. Be the exact dates what they may, we find the Egyptian of the fifth millennium B.C. in full possession of a highly organized civilization.

All subsequent ages have marveled at the pyramids, some of which date from about the year 4000 B.C , tho we may note in passing that these dates must not be taken too literally. The chronology of ancient Egypt cannot as yet be fixed with exact accuracy, but the disagreements between the various students of the subject need give us little concern. For our present purpose it does not in the least matter whether the pyramids were built three thousand or four thousand years before the beginning of our era. It suffices that they date back to a period long antecedent to the beginnings of civilization in Western Europe. They prove that the Egyptian of that early day had attained a knowledge of practical mechanics which, even from the twentieth-century point of view, is not to be spoken of lightly.

It has sometimes been suggested that these mighty

BUILDING A PYRAMID — SPHINX AND PYRAMID

pyramids, built as they are of great blocks of stone, speak for an almost miraculous knowledge on the part of their builders, but a saner view of the conditions gives no warrant for this thought

Diodorus, the Sicilian, in his famous *World's History,* written about the beginning of our era, explains the building of the pyramids by suggesting that great quantities of earth were piled against the side of the rising structure to form an inclined plane up which the blocks of stone were dragged He gives us certain figures, based, doubtless, on reports made to him by Egyptian priests, who in turn drew upon the traditions of their country, perhaps even upon written records no longer preserved He says that one hundred and twenty thousand men were employed in the construction of the largest pyramid, and that, notwithstanding the size of this host of workers, the task occupied twenty years We must not place too much dependence upon such figures as these, for the ancient historians are notoriously given to exaggeration in recording numbers; yet we need not doubt that the report given by Diodorus is substantially accurate in its main outlines as to the method through which the pyramids were constructed. A host of men putting their added weight and strength to the task, with the aid of ropes, pulleys, rollers, and levers, and utilizing the principle of the inclined plane, could undoubtedly move and elevate and place in position the largest blocks that enter into the pyramids or—what seems even more wonderful—the most gigantic obelisks, without the aid of any other kind of mechanism or of any more occult power. The same hands could, as Diodorus suggests, remove all trace of the débris of construction and leave the pyramids and obelisks in weird isolation, as if sprung into being through a miracle

COLONNADE AT LUXOR — TEMPLE FROM THE NILE

It has been necessary to bear in mind these phases of practical civilization because much that we know of the purely scientific attainments of the Egyptians is based upon modern observation of their pyramids and temples. It was early observed, for example, that the pyramids are obviously oriented as regards the direction in which they face, in strict accordance with some astronomical principle. Early in the nineteenth century the Frenchman Biot made interesting studies in regard to this subject, and a hundred years later, in our own time, Sir Joseph Norman Lockyer, following up the work of various intermediary observers, has given the subject much attention, making it the central theme of his work on *The Dawn of Astronomy*.

Lockyer's researches make it clear that in the main the temples of Egypt were oriented with reference to the point at which the sun rises on the day of the summer solstice. The time of the solstice had peculiar interest for the Egyptians, because it corresponded rather closely with the time of the rising of the Nile. The floods of that river appear with very great regularity; the onrushing tide reaches the region of Heliopolis and Memphis almost precisely on the day of the summer solstice. The time varies at different stages of the river's course, but as the civilization of the early dynasties centered at Memphis, observations made at this place had widest vogue.

Considering the all-essential character of the Nile floods—without which civilization would be impossible in Egypt—it is not strange that the time of their appearance should be taken as marking the beginning of a new year. The fact that their coming coincides with the solstice makes such a division of the calendar perfectly natural. In point of fact, from the earliest periods of

TEMPLE OF RAMSES III AT THEBES — GREAT VESTIBULE OF TEMPLE OF HATHOR

which records have come down to us, the new year of the Egyptians dates from the summer solstice. It is certain that from the earliest historical periods the Egyptians were aware of the approximate length of the year. It would be strange were it otherwise, considering the ease with which a record of days could be kept from Nile flood to Nile flood, or from solstice to solstice.

But this, of course, applies only to an approximate count. There is some reason to believe that in the earliest period the Egyptians made this count only 360 days. The fact that their year was divided into twelve months of thirty days each lends color to this belief; but, in any event, the mistake was discovered in due time and a partial remedy was applied through the interpolation of a "little month" of five days between the end of the twelfth month and the new year. This nearly but not quite remedied the matter. What it obviously failed to do was to take account of that additional quarter of a day which really rounds out the actual year.

It would have been a vastly convenient thing for humanity had it chanced that the earth had so accommodated its rotary motion with its speed of transit about the sun as to make its annual flight in precisely 360 days. Twelve lunar months of thirty days each would then have coincided exactly with the solar year, and most of the complexities of the calendar, which have so puzzled historical students, would have been avoided; but, on the other hand, perhaps this very simplicity would have proved detrimental to astronomical science by preventing men from searching the heavens as carefully as they have done.

Be that as it may, the complexity exists. The actual year of three hundred and sixty-five and (about) one-quarter days cannot be divided evenly into months, and

some such expedient as the intercalation of days here and there is essential, else the calendar will become absolutely out of harmony with the seasons.

In the case of the Egyptians, the attempt at adjustment was made, as just noted, by the introduction of the five days, constituting what the Egyptians themselves termed "the five days over and above the year." These so-called epagomenal days were undoubtedly introduced at a very early period Maspero holds that they were in use before the first Thinite dynasty, citing in evidence the fact that the legend of Osiris explains these days as having been created by the god Thot in order to permit Nuit to give birth to all her children; this expedient being necessary to overcome a ban which had been pronounced against Nuit, according to which she could not give birth to children on any day of the year.

But, of course, the five additional days do not suffice fully to rectify the calendar. There remains the additional quarter of a day to be accounted for. This, of course, amounts to a full day every fourth year. We shall see that later Alexandrian science hit upon the expedient of adding a day to every fourth year; an expedient which the Julian calendar adopted and which still gives us our familiar leap-year. But, unfortunately, the ancient Egyptian failed to recognize the need of this additional day, or if he did recognize it he failed to act on his knowledge, and so it happened that, starting somewhere back in the remote past with a new year's day that coincided with the inundation of the Nile, there was a constantly shifting maladjustment of calendar and seasons as time went on.

The Egyptian seasons, it should be explained, were three in number: the season of the inundation, the season of the seed-time, and the season of the harvest; each

season being, of course, four months in extent Originally, as just mentioned, the season of the inundations began and coincided with the actual time of inundation. The more precise fixing of new year's day was accomplished through observation of the time of the so-called heliacal rising of the dog-star, Sirius, which bore the Egyptian name Sothis.

It chances that, as viewed from about the region of Heliopolis, the sun at the time of the summer solstice occupies an apparent position in the heavens close to the dog-star. Now, as is well known, the Egyptians, seeing divinity back of almost every phenomenon of nature, very naturally paid particular reverence to so obviously influential a personage as the sun-god. In particular they thought it fitting to do homage to him just as he was starting out on his tour of Egypt in the morning; and that they might know the precise moment of his coming, the Egyptian astronomer priests, perched on the hilltops near their temples, were wont to scan the eastern horizon with reference to some star which had been observed to precede the solar luminary. Of course the precession of the equinoxes, due to that axial wobble in which our clumsy earth indulges, would change the apparent position of the fixed stars in reference to the sun, so that the same star could not do service as heliacal messenger indefinitely; but, on the other hand, these changes are so slow that observations by many generations of astronomers would be required to detect the shifting.

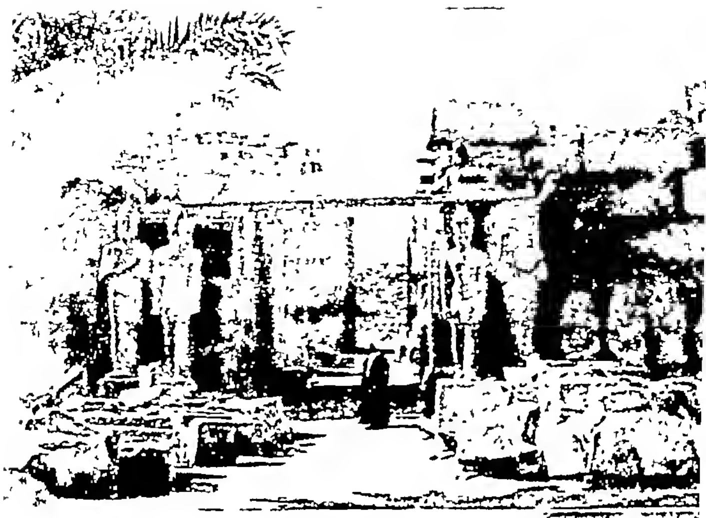
It is believed by Lockyer, tho the evidence is not quite demonstrative, that the astronomical observations of the Egyptians date back to a period when Sothis, the dog-star, was not in close association with the sun on the morning of the summer solstice. Yet, according to the

TEMPLE AT ABYDOS

calculations of Biot, the heliacal rising of Sothis at the solstice was noted as early as the year 3285 B C, and it is certain that this star continued throughout subsequent centuries to keep this position of peculiar prestige. Hence it was that Sothis came to be associated with Isis, one of the most important divinities of Egypt, and that the day in which Sothis was first visible in the morning sky marked the beginning of the new year, that day coinciding, as already noted, with the summer solstice and with the beginning of the Nile flow

But now for the difficulties introduced by that unreckoned quarter of a day Obviously with a calendar of 365 days only, at the end of four years, the calendar year, or vague year, as the Egyptians came to call it, had gained by one full day upon the actual solar year—that is to say, the heliacal rising of Sothis, the dog-star, would not occur on new year's day of the faulty calendar, but a day later. And with each succeeding period of four years the day of heliacal rising, which marked the true beginning of the year—and which still, of course, coincided with the inundation—would have fallen another day behind the calendar. In the course of 120 years an entire month would be lost; and in 480 years so great would become the shifting that the seasons would be altogether misplaced; the actual time of inundations corresponding with what the calendar registered as the seed-time, and the actual seed-time in turn corresponding with the harvest-time of the calendar.

At first thought this seems very awkward and confusing, but in all probability the effects were by no means so much so in actual practise. We need go no farther than to our own experience to know that the names of seasons, as of months and days, come to have



TEMPLES AT KARNAK (THOTMES III)
AND LUXOR (RAMSES II)

in the minds of most of us a purely conventional significance. Few of us stop to give a thought to the meaning of the words January, February, etc., except as they connote certain climatic conditions If, then, our own calendar were so defective that in the course of 120 years the month of February had shifted back to occupy the position of the original January, the change would have been so gradual, covering the period of two lifetimes or of four or five average generations, that it might well escape general observation

Each succeeding generation of Egyptians, then, may not improbably have associated the names of the seasons with the contemporary climatic conditions, troubling themselves little with the thought that in an earlier age the climatic conditions for each period of the calendar were quite different. We cannot well suppose, however, that the astronomer priests were oblivious to the true state of things Upon them devolved the duty of predicting the time of the Nile flood; a duty they were enabled to perform without difficulty through observation of the rising of the solstitial sun and its Sothic messenger. To these observers it must finally have been apparent that the shifting of the seasons was at the rate of one day in four years; this known, it required no great mathematical skill to compute that this shifting would finally effect a complete circuit of the calendar, so that after ($4 \times 365 =$) 1460 years the first day of the calendar year would again coincide with the heliacal rising of Sothis and with the coming of the Nile flood. In other words, 1461 vague years or Egyptian calendar years of 365 days each correspond to 1460 actual solar years of 365¼ days each. This period, measured thus by the heliacal rising of Sothis, is spoken of as the Sothic cycle.

PTOLEMY GATEWAY, KARNAK — TEMPLE OF HORUS, EDFU

To us who are trained from childhood to understand that the year consists of (approximately) 365¼ days, and to know that the calendar may be regulated approximately by the introduction of an extra day every fourth year, this recognition of the Sothic cycle seems simple enough Yet if the average man of us will reflect how little he knows, of his own knowledge, of the exact length of the year, it will soon become evident that the appreciation of the faults of the calendar and the knowledge of its periodical adjustment constituted a relatively high development of scientific knowledge on the part of the Egyptian astronomer

It may be added that various efforts to reform the calendar were made by the ancient Egyptians, but that they cannot be credited with a satisfactory solution of the problem; for, of course, the Alexandrian scientists of the Ptolemaic period (whose work we shall have occasion to review presently) were not Egyptians in any proper sense of the word, but Greeks.

Since so much of the time of the astronomer priests was devoted to observation of the heavenly bodies, it is not surprizing that they should have mapped out the apparent course of the moon and the visible planets in their nightly tour of the heavens, and that they should have divided the stars of the firmament into more or less arbitrary groups or constellations. That they did so is evidence by various sculptured representations of constellations corresponding to signs of the zodiac which still ornament the ceilings of various ancient temples.

Unfortunately the decorative sense, which was always predominant with the Egyptian sculptor, led him to take various liberties with the distribution of figures in these representations of the constellations, so that the inferences drawn from them as to the exact map of the

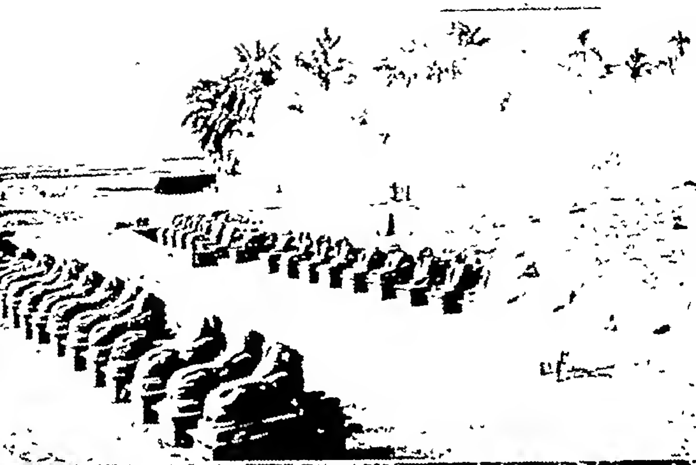
TOMB OF TUT-ANKH-AMEN, THEBES — TEMPLE OF HORUS, EDFU

heavens as the Egyptians conceived it cannot be fully relied upon. It appears, however, that the Egyptian astronomer divided the zodiac into twenty-four decani, or constellations The arbitrary groupings of figures, with the aid of which these are delineated, bear a close resemblance to the equally arbitrary outlines which we are still accustomed to use for the same purpose.

In viewing this astronomical system of the Egyptians one cannot avoid the question as to just what interpretation was placed upon it as regards the actual mechanical structure of the universe. A proximal answer to the question is supplied us with a good deal of clearness

It appears that the Egyptian conceived the sky as a sort of tangible or material roof placed above the world, and supported at each of its four corners by a column or pillar, which was later regarded as a great mountain. The earth itself was conceived to be a rectangular box, longer from north to south than from east to west; the upper surface of this box, upon which man lived, being slightly concave and having, of course, the valley of the Nile as its center.

The pillars of support were situated at the points of the compass; the northern one being located beyond the Mediterranean Sea; the southern one away beyond the habitable regions toward the source of the Nile, and the eastern and western ones in equally inaccessible regions. Circling about the southern side of the world was a great river suspended in mid-air on something comparable to mountain cliffs; on which river the sun-god made his daily course in a boat, fighting day by day his ever-recurring battle against Set, the demon of darkness. The wide channel of this river enabled the sun-god to alter his course from time to time, as he is observed to do; in winter directing his bark toward the farther bank of



AVENUE OF SPHINXES, KARNAK — SET OFFERING TO THE SACRED BOAT, ABYDOS

the channel; in summer gliding close to the nearer bank

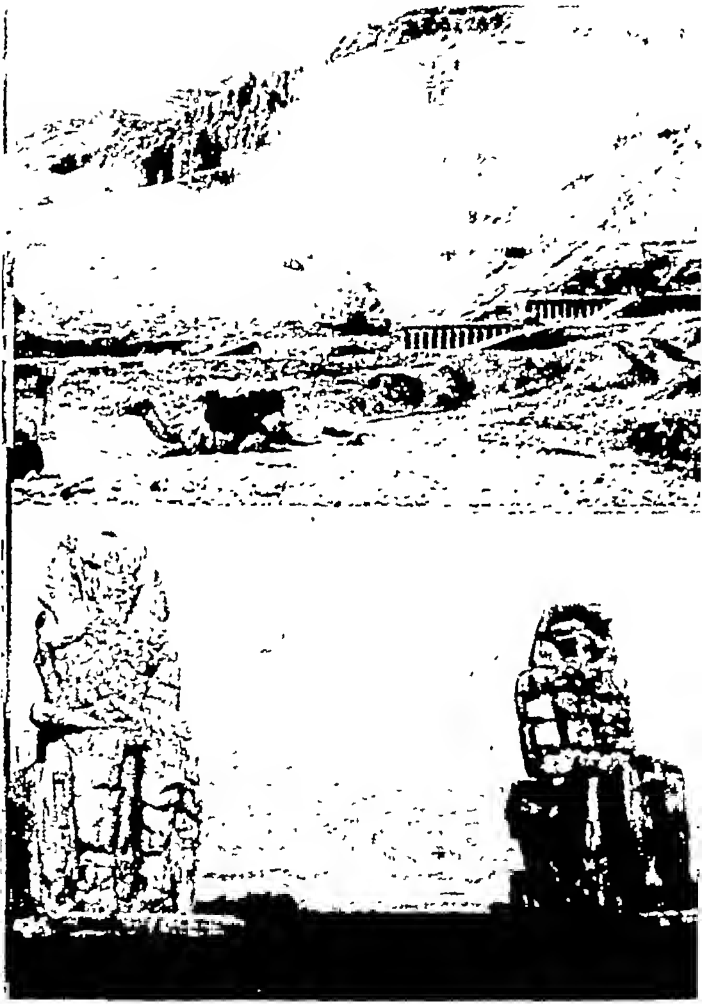
As to the stars, they were similar lights, suspended from the vault of the heaven; but just how their observed motion of translation across the heavens was explained is not apparent. It is more than probable that no one explanation was universally accepted

In explaining the origin of this mechanism of the heavens, the Egyptian imagination ran riot Each separate part of Egypt had its own hierarchy of gods, and more or less its own explanations of cosmogony There does not appear to have been any one central story of creation that found universal acceptance, any more than there was one specific deity everywhere recognized as supreme among the gods.

Perhaps the most interesting of the cosmogonic myths was that which conceived that Nuit, the goddess of night, had been torn from the arms of her husband, Sibû the earth-god, and elevated to the sky despite her protests and her husband's struggles, there to remain supported by her four limbs, which became metamorphosed into the pillars or mountains already mentioned. The forcible elevation of Nuit had been effected on the day of creation by a new god, Shu, who came forth from the primeval waters.

A painting on the mummy case of one Betuhamon, now in the Turin Museum, illustrates, in the graphic manner so characteristic of the Egyptians, this act of creation. As Maspero points out, the struggle of Sibû resulted in contorted attitudes to which the irregularities of the earth's surface are to be ascribed.

In contemplating such a scheme of celestial mechanics as that just outlined, one cannot avoid raising the question as to just the degree of literalness which the Egyptians themselves put upon it. We know how essentially



THEBES: TEMPLE OF A QUEEN —
COLOSSI OF MEMNON

eye-minded the Egyptian was, to use a modern psychological phrase—that is to say, how essential to him it seemed that all his conceptions should be visualized. The evidences of this are everywhere: all his gods were made tangible; he believed in the immortality of the soul, yet he could not conceive of such immortality except in association with an immortal body; he must mummify the body of the dead, else, as he firmly believed, the dissolution of the spirit would take place along with the dissolution of the body itself.

His world was peopled everywhere with spirits, but they were spirits associated always with corporeal bodies; his gods found lodgment in sun and moon and stars; in earth and water, in the bodies of reptiles and birds and mammals. He worshiped all of these things: the sun, the moon, water, earth, the spirit of the Nile, the ibis, the cat, the ram, and apis the bull; but, so far as we can judge, his imagination did not reach to the idea of an absolutely incorporeal deity.

Similarly his conception of the mechanism of the heavens must be a tangibly mechanical one. He must think of the starry firmament as a substantial entity which could not defy the law of gravitation, and which, therefore, must have the same manner of support as is required by the roof of a house or temple. We know that this idea of the materiality of the firmament found elaborate expression in those later cosmological guesses which were to dominate the thought of Europe until the time of Newton.

We need not doubt, therefore, that for the Egyptian this solid vault of the heavens had a very real existence. If now and then some dreamer conceived the great bodies of the firmament as floating in a less material plenum—and such iconoclastic dreamers there are in

all ages—no record of his musings has come down to us, and we must freely admit that if such thoughts existed they were alien to the character of the Egyptian mind as a whole.

While the Egyptians conceived the heavenly bodies as the abiding-place of various of their deities, it does not appear that they practised astrology in the later acceptance of that word. This is the more remarkable since the conception of lucky and unlucky days was carried by the Egyptians to the extremes of absurdity.

"One day was lucky or unlucky," says Erman, "according as a good or bad mythological incident took place on that day. For instance, the 1st of Mechir, on which day the sky was raised, and the 27th of Athyr, when Horus and Set concluded peace together and divided the world between them, were lucky days; on the other hand, the 14th of Tybi, on which Isis and *Nephthys mourned for Osiris, was an unlucky day.*

"With the unlucky days, which fortunately were less in number than the lucky days, they distinguished different degrees of ill-luck. Some were very unlucky. others only threatened ill-luck, and many, like the 17th and the 27th Choiakh, were partly good and partly bad according to the time of day. Lucky days might, as a rule, be disregarded. At most it might be as well to visit some specially renowned temple, or to 'celebrate a joyful day at home,' but no particular precautions were really necessary; and, above all, it was said, 'what thou also seest on the day is lucky.'

"It was quite otherwise with the unlucky and dangerous days, which imposed so many and such great limitations on people that those who wished to be prudent were always obliged to bear them in mind when determining on any course of action Certain conditions were

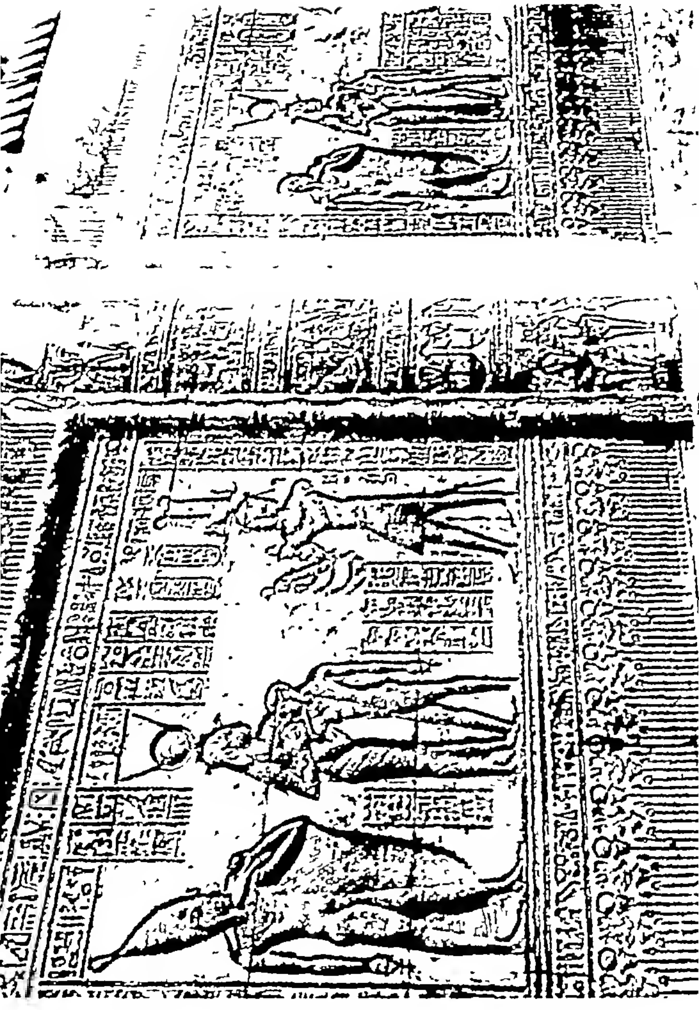
easy to carry out. Music and singing were to be avoided on the 14th Tybi, the day of the mourning of Osiris, and no one was allowed to wash on the 16th Tybi; whilst the name of Set might not be pronounced on the 24th of Pharmuthi. Fish was forbidden on certain days; and what was still more difficult in a country so rich in mice, on the 12th of Tybi no mouse might be seen

"The most tiresome prohibitions, however, were those which occurred not infrequently, namely, those concerning work and going out: for instance, four times in Paophi the people had to 'do nothing at all,' and five times to sit the whole day or half the day in the house; and the same rule had to be observed each month. It was impossible to rejoice if a child was born on the 23rd of Thoth; the parents knew it could not live. Those born on the 20th of Choiakh would become blind, and those born on the 3d of Choiakh, deaf."

Where such conceptions as these pertained, it goes without saying that charms and incantations intended to break the spell of the unlucky omens were equally prevalent.

Such incantations consisted usually of the recitation of certain phrases based originally, it would appear, upon incidents in the history of the gods. The words which the god had spoken in connection with some lucky incident would, it was thought, prove effective now in bringing good luck to the human supplicant—that is to say, the magician hoped through repeating the words of the god to exercise the magic power of the god.

It was even possible, with the aid of the magical observances, partly to balk fate itself. Thus the person predestined through birth on an unlucky day to die of a serpent bite might postpone the time of this fateful visitation to extreme old age. The like uncertainty at-



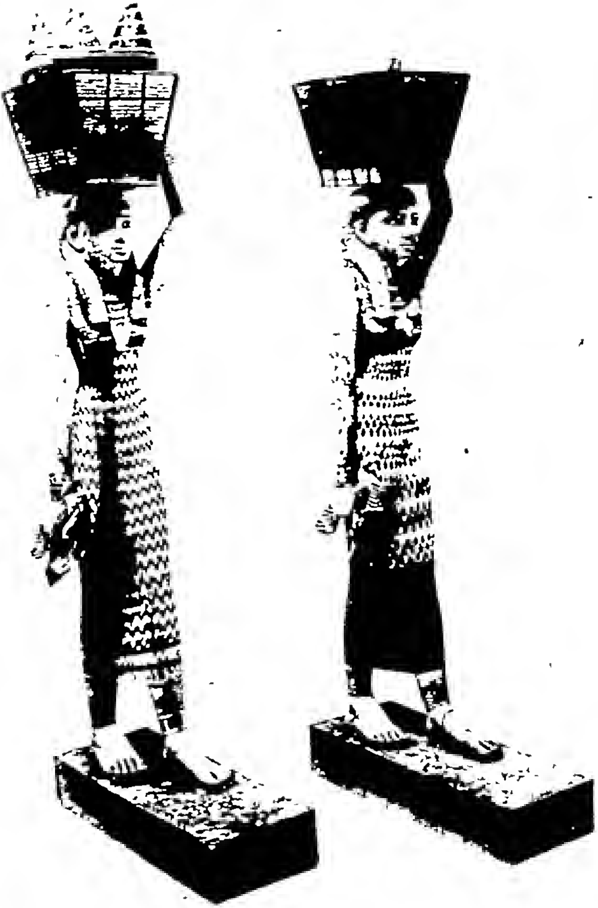
PTOLEMY OFFERING TO ISIS AND HORUS (DENDERAH)

tached to those spells which one person was supposed to be able to exercise over another It was held, for example, that if something belonging to an individual, such as a lock of hair or a paring of the nails, could be secured and incorporated in a waxen figure, this figure would be intimately associated with the personality of that individual. An enemy might thus secure occult power over one; any indignity practised upon the waxen figure would result in like injury to its human prototype If the figure were bruised or beaten, some accident would overtake its double; if the image were placed over a fire, the human being would fall into a fever, and so on But, of course, such mysterious evils as these would be met and combated by equally mysterious processes; and so it was that the entire art of medicine was closely linked with magical practises.

As to the actual scientific attainments of the Egyptian physician, it is difficult to speak with precision. Despite the cumbersome formulæ and the grotesque incantations, we need not doubt that a certain practical value attended his therapeutics. He practised almost pure empiricism, however, and certainly it must have been almost impossible to determine which ones, if any, of the numerous ingredients of the prescription had real efficacy.

The practical anatomical knowledge of the physician, there is every reason to believe, was extremely limited At first thought it might seem that the practise of embalming would have led to the custom of dissecting human bodies, and that the Egyptians, as a result of this, would have excelled in the knowledge of anatomy. But the actual results were rather the reverse of this.

Embalming the dead, it must be recalled, was a purely religious observance. It took place under the superintendence of the priests, but so great was the reverence



ANCIENT EGYPT

for the human body that the priests themselves were not permitted to make the abdominal incision which was a necessary preliminary of the process This incision, as we are informed by both Herodotus and Diodorus, was made by a special officer, whose status, if we may believe the explicit statement of Diodorus, was quite comparable to that of the modern hangman.

The paraschistas, as he was called, having performed his necessary but obnoxious function with the aid of a sharp Ethiopian stone, retired hastily, leaving the remaining processes to the priests These, however, confined their observations to the abdominal viscera; under no consideration did they make other incisions in the body. It follows, therefore, that their opportunity for anatomical observations was most limited

Since even the necessary mutilation inflicted on the corpse was regarded with such horror, it follows that anything in the way of dissection for a less sacred purpose was absolutely prohibited. Probably the same prohibition extended to a large number of animals, since most of these were held sacred in one part of Egypt or another. Moreover, there is nothing in what we know of the Egyptian mind to suggest the probability that any Egyptian physician would make extensive anatomical observations for the love of pure knowledge. All Egyptian science is eminently practical.

If we think of the Egyptian as mysterious, it is because of the superstitious observances that we everywhere associate with his daily acts; but these, as we have already tried to make clear, were really based on scientific observations of a kind, and the attempt at true inferences from these observations But whether or not the Egyptian physician desired anatomical knowledge, the results of his inquiries were certainly most meager.

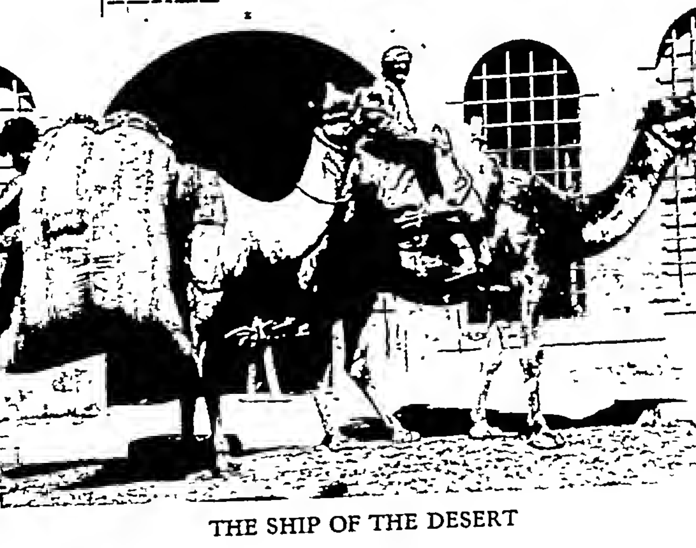
TODAY AND YESTERDAY IN EGYPT

The essentials of his system had to do with a series of vessels, alleged to be twenty-two or twenty-four in number, which penetrated the head and were distributed in pairs to the various members of the body, and which were vaguely thought of as carriers of water, air, excretory fluids, etc

Yet back of this vagueness, as must not be overlooked, there was an all-essential recognition of the heart as the central vascular organ The heart is called the beginning of all the members Its vessels, we are told, "lead to all the members; whether the doctor lays his finger on the forehead, on the back of the head, on the hands, on the place of the stomach (?), on the arms, or on the feet, everywhere he meets with the heart, because its vessels lead to all the members" This recognition of the pulse must be credited to the Egyptian physician as a piece of practical knowledge, in some measure offsetting the vagueness of his anatomical theories

But, indeed, practical knowledge was, as has been said over and over, the essential characteristic of Egyptian science. Yet another illustration of this is furnished us if we turn to the more abstract departments of thought and inquire what were the Egyptian attempts in such a field as mathematics The answer does not tend greatly to increase our admiration for the Egyptian mind. We are led to see, indeed, that the Egyptian merchant was able to perform all the computations necessary to his craft, but we are forced to conclude that the knowledge of numbers scarcely extended beyond this, and that even here the methods of reckoning were tedious and cumbersome.

Our knowledge of the subject rests largely upon the so-called papyrus Rhind, which is a sort of mythological hand-book of the ancient Egyptians. Analyzing this



THE SHIP OF THE DESERT

document, Professor Erman concludes that the knowledge of the Egyptians was adequate to all practical requirements. Their mathematics taught them "how in the exchange of bread for beer the respective value was to be determined when converted into a quantity of corn; how to reckon the size of a field; how to determine how a given quantity of corn would go into a granary of a certain size," and like every-day problems.

Yet they were obliged to make some of their simple computations in a very roundabout way. It would appear, for example, that their mental arithmetic did not enable them to multiply by a number larger than two, and that they did not reach a clear conception of complex fractional numbers. They did, indeed, recognize that each part of an object divided into 10 pieces became $\frac{1}{10}$ of that object; they even grasped the idea of $\frac{2}{3}$, this being a conception easily visualized; but they apparently did not visualize such a conception as $^{3}/_{10}$, except in the crude form of $\frac{1}{10}$ plus $\frac{1}{10}$ plus $\frac{1}{10}$. Their entire idea of division seems defective. They view the subject from the more elementary standpoint of multiplication. Thus, in order to find out how many times 7 is contained in 77, an existing example shows that the numbers representing 1 times 7, 2 times 7, 4 times 7, 8 times 7 were set down successively and various experimental additions made to find out which sets of these numbers aggregated 77.

—1	7
—2	14
4	28
—8	56

A line before the first, second, and fourth of these numbers indicated that it is necessary to multiply 7 by 1

plus 2 plus 8—that is, by 11, in order to obtain 77; that is to say, 7 goes 11 times in 77.

All this seems very cumbersome indeed, yet we must not overlook the fact that the process which goes on in our own minds in performing such a problem as this is precisely similar, except that we have learned to slur over certain of the intermediate steps with the aid of a memorized multiplication table. In the last analysis, division is only the obverse side of multiplication, and any one who has not learned his multiplication table is reduced to some such expedient as that of the Egyptian Indeed, whenever we pass beyond the range of our memorized multiplication table—which for most of us ends with the twelves—the experimental character of the trial multiplication through which division is finally effected does not so greatly differ from the experimental efforts which the Egyptian was obliged to apply to smaller numbers.

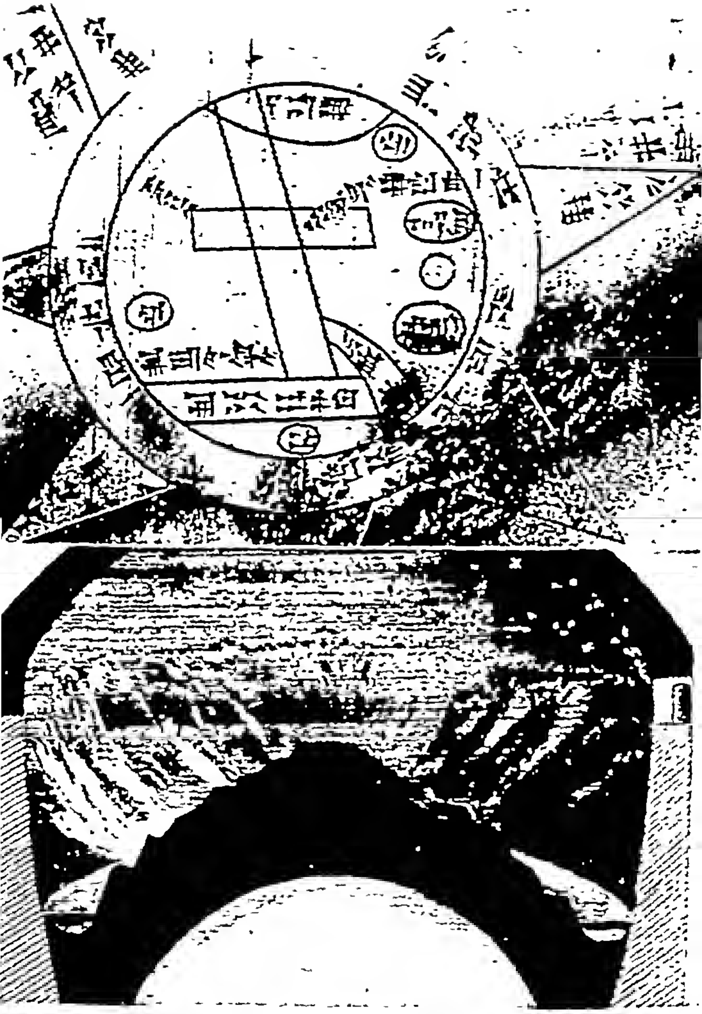
Despite his defective comprehension of fractions, the Egyptian was able to work out problems of relative complexity; for example, he could determine the answer of such a problem as this: a number together with its fifth part makes 21; what is the number? The process by which the Egyptian solved this problem seems very cumbersome to any one for whom a rudimentary knowledge of algebra makes it simple, yet the method which we employ differs only in that we are enabled, thanks to our hypothetical *x*, to make a short cut, and the essential fact must not be overlooked that the Egyptian reached a correct solution of the problem.

With all due desire to give credit, however, the fact remains that the Egyptian was but a crude mathematician. Here, as elsewhere, it is impossible to admire him for any high development of theoretical science.

First, last, and all the time, he was practical, and there is nothing to show that the thought of science for its own sake, for the mere love of knowing, ever entered his head.

In general, then, we must admit that the Egyptian had not progressed far in the hard way of abstract thinking. He worshiped everything about him because he feared the result of failing to do so He embalmed the dead lest the spirit of the neglected one might come to torment him. Eye-minded as he was, he came to have an artistic sense, to love decorative effects. But he let these always take precedence over his sense of truth; as, for example, when he modified his lists of kings at Abydos to fit the space which the architect had left to be filled; he had no historical sense to show to him that truth should take precedence over mere decoration.

And everywhere he lived in the same happy-gô-lucky way. He loved personal ease, the pleasures of the table, the luxuries of life, games, recreations, festivals He took no heed for the morrow, except as the morrow might minister to his personal needs. Essentially a sensual being, he scarcely conceived the meaning of the intellectual life in the modern sense of the term. He had perforce learned some things about astronomy, because these were necessary to his worship of the gods; about practical medicine, because this ministered to his material needs; about practical arithmetic, because this aided him in every-day affairs The bare rudiments of an historical science may be said to be crudely outlined in his defective lists of kings. But beyond this he did not go. Science as science, and for its own sake, was unknown to him. The conception of Minerva, goddess of wisdom, was reserved for the creative genius of another people.



BABYLONIAN MAP — CHALDEAN
CONCEPTION OF THE COSMOS

III

SCIENCE OF BABYLONIA AND ASSYRIA

THROUGHOUT classical antiquity Egyptian science was famous. We know that Plato spent some years in Egypt in the hope of penetrating the alleged mysteries of its fabled learning; and the story of the Egyptian priest who patronizingly assured Solon that the Greeks were but babes was quoted everywhere without disapproval. Even so late as the time of Augustus, we find Diodorus, the Sicilian, looking back with veneration upon the Oriental learning, to which Pliny also refers with unbounded respect.

From what we have seen of Egyptian science, all this furnishes us with a somewhat striking commentary upon the attainments of the Greeks and Romans themselves. To refer at length to this would be to anticipate our purpose; what now concerns us is to recall that all along there was another nation, or group of nations, that disputed the palm for scientific attainments. This group of nations found a home in the valley of the Tigris and Euphrates. Their land was named Mesopotamia by the Greeks, because a large part of it lay between the two rivers just mentioned. The peoples themselves are familiar to every one as the Babylonians and the Assyrians.

These peoples were of Semitic stock—allied, therefore, to the ancient Hebrews and Phenicians and of the same racial stem with the Arameans and Arabs.

The great capital of the Babylonians during the later

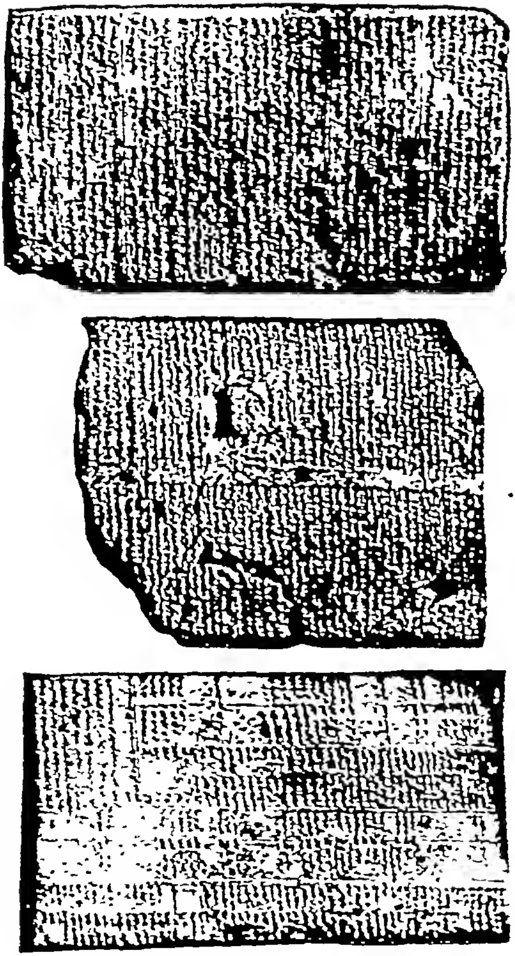
INSCRIBED BABYLONIAN MONUMENT

period of their history was the famed city of Babylon itself; the most famous capital of the Assyrians was Nineveh, that city to which, as every Bible-student will recall, the prophet Jonah was journeying when he had a much-exploited experience, the record of which forms no part of scientific annals. It was the kings of Assyria, issuing from their palaces in Nineveh, who dominated the civilization of Western Asia during the heyday of Hebrew history, and whose deeds are so frequently mentioned in the Hebrew chronicles

Later on, in the year 606 B.C., Nineveh was overthrown by the Medes and Babylonians. The famous city was completely destroyed, never to be rebuilt. Babylon, however, tho conquered subsequently by Cyrus and held in subjection by Darius, the Persian kings, continued to hold sway as a great world-capital for some centuries. The last great historical event that occurred within its walls was the death of Alexander the Great, which took place there in the year 322 B.C.

In the time of Herodotus the fame of Babylon was at its height, and the father of history has left us a most entertaining account of what he saw when he visited the wonderful capital. Unfortunately, Herodotus was not a scholar in the proper acceptance of the term. He probably had no inkling of the Babylonian language, so the voluminous records of its literature were entirely shut off from his observation. He therefore enlightens us but little regarding the science of the Babylonians, tho his observations on their practical civilization give us incidental references of no small importance.

Somewhat more detailed references to the scientific attainments of the Babylonians are found in the fragments that have come down to us of the writings of



BABYLONIAN TABLETS: LETTER OF 1450 B C
CHRONICLE OF 668 B C

the great Babylonian historian, Berosus, who was born in Babylon about 330 B.C., and who was, therefore, a contemporary of Alexander the Great. But the writings of Berosus also, or at least such parts of them as have come down to us, leave very much to be desired in point of explicitness. They give some glimpses of Babylonian history, and they detail at some length the strange mythical tales of creation that entered into the Babylonian conception of cosmogony—details which find their counterpart in the allied recitals of the Hebrews. But taken all in all, the glimpses of the actual state of Chaldean learning, as it was commonly called, amounted to scarcely more than vague wonder-tales

No one really knew just what interpretation to put upon these tales until the explorers of the nineteenth century had excavated the ruins of the Babylonian and Assyrian cities, bringing to light the relics of their wonderful civilization. But these relics fortunately included vast numbers of written documents, inscribed on tablets, prisms, and cylinders of terra-cotta. When nineteenth-century scholarship had penetrated the mysteries of the strange script, and ferreted out the secrets of an unknown tongue, the world at last was in possession of authentic records by which the traditions regarding the Babylonians and Assyrians could be tested Thanks to these materials, a new science commonly spoken of as Assyriology came into being, and a most important chapter of human history was brought to light.

It became apparent that the Greek ideas concerning Mesopotamia, tho vague in the extreme, were founded on fact. No one any longer questions that the Mesopotamian civilization was fully on a par with that of Egypt; indeed, it is rather held that superiority lay with the Asiatics. Certainly, in point of purely scientific

OBELISK OF KING SHALMANESER II

attainments, the Babylonians passed somewhat beyond their Egyptian competitors All the evidence seems to suggest also that the Babylonian civilization was even more ancient than that of Egypt The precise dates are here in dispute; nor for our present purpose need they greatly concern us But the Assyrio-Babylonian records have much greater historical accuracy as regards matters of chronology than have the Egyptian, and it is believed that our knowledge of the early Babylonian history is carried back, with some certainty, to King Sargon of Agade, for whom the date 3800 B C is generally accepted, while somewhat vaguer records give us glimpses of periods as remote as the sixth, perhaps even the seventh or eighth millenniums before our era

At a very early period Babylon itself was not a capital and Nineveh had not come into existence. The important cities, such as Nippur and Shirpurla, were situated farther to the south It is on the site of these cities that the recent excavations have been made, such as those of the University of Pennsylvania expeditions at Nippur, which are giving us glimpses into remoter recesses of the historical period.

Even if we disregard the more problematical early dates, we are still concerned with the records of a civilization extending unbroken throughout a period of about four thousand years; the actual period is in all probability twice or thrice that

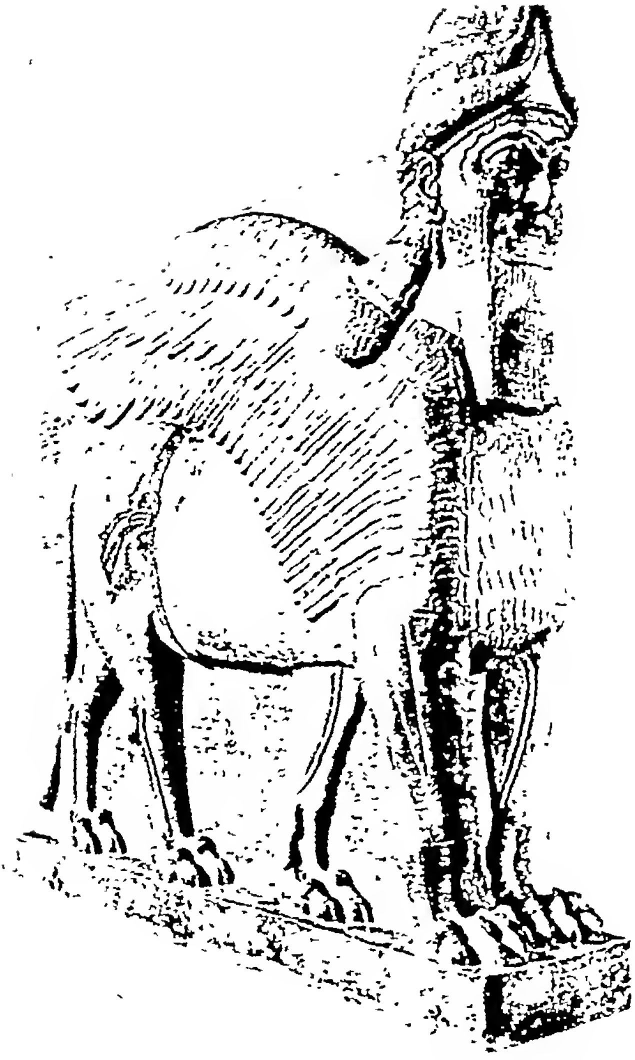
Naturally enough, the current of history is not an unbroken stream throughout this long epoch. It appears that at least two utterly different ethnic elements are involved. A preponderance of evidence seems to show that the earliest civilized inhabitants of Mesopotamia were not Semitic, but an alien race, which is now commonly spoken of as Sumerian. This people, of whom

INSCRIBED ETRUSCAN (ABOVE) AND HITTITE SCULPTURES

we catch glimpses chiefly through the records of its successors, appears to have been subjugated or overthrown by Semitic invaders, who, coming perhaps from Arabia (their origin is in dispute), took possession of the region of the Tigris and Euphrates, learned from the Sumerians many of the useful arts, and, partly perhaps because of their mixed lineage, were enabled to develop the most wonderful civilization of antiquity.

Could we analyze the details of this civilization from its earliest to its latest period we should of course find the same changes which always attend racial progress and decay. We should then be able, no doubt, to speak of certain golden epochs and their periods of decline. To a certain meager extent we are able to do this now. We know, for example, that King Hammurabi, who lived about 2200 B C., was a great lawgiver, the ancient prototype of Justinian; and the epochs of such Assyrian kings as Sargon II., Asshurnazirpal, Sennacherib, and Asshurbanapal stand out with much distinctness.

Yet, as a whole, the record does not enable us to trace with clearness the progress of scientific thought. At best we can gain fewer glimpses in this direction than in almost any other, for it is the record of war and conquest rather than of the peaceful arts that commanded the attention of the ancient scribe. So in dealing with the scientific achievements of these peoples we shall perforce consider their varied civilizations as a unity, and attempt, as best we may, to summarize their achievements as a whole. For the most part, we shall not attempt to discriminate as to what share in the final product was due to Sumerian, what to Babylonian, and what to Assyrian. We shall speak of Babylonian science as including all these elements; and drawing our information chiefly from the relatively late Assyrian and



INSCRIBED ASSYRIAN SCULPTURE

Babylonian sources, which, therefore, represent the culminating achievements of all these ages of effort, we shall attempt to discover what was the actual status of Mesopotamian science at its climax

In so far as we succeed, we shall be able to judge what scientific heritage Europe received from the Orient; for in the records of Babylonian science we have to do with the Eastern mind at its best

Let us turn to the specific inquiry as to the achievements of the Chaldean scientist whose fame so dazzled the eyes of his contemporaries of the classic world.

Our first concern naturally is astronomy, this being here, as in Egypt, the first-born and the most important of the sciences. The fame of the Chaldean astronomer was indeed what chiefly commanded the admiration of the Greeks, and it was through the results of astronomical observations that Babylonia transmitted her most important influences to the Western world. "Our division of time is of Babylonian origin," says Hommel; "to Babylonia we owe the week of seven days, with the names of the planets for the days of the week, and the division into hours and months" Hence the almost personal interest which we of today must needs feel in the efforts of the Babylonian star-gazer.

It must not be supposed, however, that the Chaldean astronomer had made any very extraordinary advances upon the knowledge of the Egyptian "watchers of the night." After all, it required patient observation rather than any peculiar genius in the observer to note in the course of time such broad astronomical conditions as the regularity of the moon's phases, and the relation of the lunar periods to the longer periodical oscillations of the sun Nor could the wanderings of the planets escape the attention of even a moderately keen observer.

The chief distinction between the Chaldean and Egyptian astronomers appears to have consisted in the relative importance they attached to various of the phenomena which they both observed. The Egyptian, as we have seen, centered his attention upon the sun. That luminary was the abode of one of his most important gods. His worship was essentially solar The Babylonian, on the other hand, appears to have been peculiarly impressed with the importance of the moon He could not, of course, overlook the attention-compelling fact of the solar year; but his unit of time was the lunar period of thirty days, and his year consisted of twelve lunar periods, or 360 days. He was perfectly aware, however, that this period did not coincide with the actual year; but the relative unimportance which he ascribed to the solar year is evidenced by the fact that he interpolated an added month to adjust the calendar only once in six years.

Indeed, it would appear that the Babylonians and Assyrians did not adopt precisely the same method of adjusting the calendar, since the Babylonians had two intercalar months called Elul and Adar, whereas the Assyrians had only a single such month, called the second Adar (the Ve'Adar of the Hebrews). This diversity further emphasizes the fact that it was the lunar period which received chief attention, the adjustment of this period with the solar seasons being a necessary expedient of secondary importance

It is held that these lunar periods have often been made to do service for years in the Babylonian computations and in the allied computations of the early Hebrews. The lives of the Hebrew patriarchs, for example, as recorded in the Bible, are perhaps reckoned in lunar "years." Divided by twelve, the "years" of

Methuselah accord fairly with the usual experience of mankind.

Yet, on the other hand, the convenience of the solar year in computing long periods of time was not unrecognized, since this period is utilized in reckoning the reigns of the Assyrian kings. It may be added that the reign of a king "was not reckoned from the day of his accession, but from the Assyrian new year's day, either before or after the day of accession. There does not appear to have been any fixed rule as to which new year's day should be chosen, but from the number of known cases, it appears to have been the general practise to count the reigning years from the new year's day nearest the accession, and to call the period between the accession day and the first new year's day 'the beginning of the reign,' when the year from the new year's day was called the first year, and the following ones were brought successively from it. Notwithstanding, in the dates of several Assyrian and Babylonian sovereigns there are cases of the year of accession being considered as the first year, thus giving two reckonings for the reigns of various monarchs, among others, Shalmaneser, Sennacherib, Nebuchadrezzar."

This uncertainty as to the years of reckoning again emphasizes the fact that the solar year did not have for the Assyrians quite the same significance that it has for us.

The Assyrian month commenced on the evening when the new moon was first observed, or, in case the moon was not visible, the new month started thirty days after the last month. Since the actual lunar period is about twenty-nine and one-half days, a practical adjustment was required between the months themselves, and this was probably effected by counting alternate months as only 29 days in length

ASSYRIAN KING OFFERING A LIBATION

Mr. R. Campbell Thompson is led by his studies of the astrological tablets to emphasize this fact. He believes that "the object of the astrological reports which related to the appearance of the moon and sun was to help determine and foretell the length of the lunar month." Mr. Thompson believes also that there is evidence to show that the intercalary month was added at a period less than six years.

In point of fact, it does not appear to be quite clearly established as to precisely how the adjustment of days with the lunar months, and lunar months with the solar year, was effected It is clear, however, according to Smith, "that the first 28 days of every month were divided into four weeks of seven days each; the seventh, fourteenth, twenty-first, twenty-eighth days respectively being Sabbaths, and that there was a general prohibition of work on these days." Here, of course, is the foundation of the Hebrew system of Sabbatical days which we have inherited.

The sacredness of the number seven itself—the belief in which has not been quite shaken off even to this day —was deduced by the Assyrian astronomer from his observation of the seven planetary bodies—namely, Sin (the moon), Samas (the sun), Umunpawddu (Jupiter), Dilbat (Venus), Kaimanu (Saturn), Gudud (Mercury), Mustabarru-mutanu (Mars). Twelve lunar periods, making up approximately the solar year, gave peculiar importance to the number twelve also. Thus the zodiac was divided into twelve signs which astronomers of all subsequent times have continued to recognize; and the duodecimal system of counting took precedence with the Babylonian mathematicians over the more primitive and, as it seems to us, more satisfactory decimal system.

Another discrepancy between the Babylonian and Egyptian years appears in the fact that the Babylonian new year dates from about the period of the vernal equinox and not from the solstice. Lockyer associates this with the fact that the periodical inundation of the Tigris and Euphrates occurs about the equinoctial period, whereas, as we have seen, the Nile flood comes at the time of the solstice. It is but natural that so important a phenomenon as the Nile flood should make a strong impression upon the minds of a people living in a valley.

The fact that occasional excessive inundations have led to most disastrous results is evidenced in the incorporation of stories of the almost total destruction of mankind by such floods among the myth tales of all peoples who reside in valley countries. The flooding of the Tigris and Euphrates had not, it is true, quite the same significance for the Mesopotamians that the Nile flood had for the Egyptians. Nevertheless it was a most important phenomenon, and may very readily be imagined to have been the most tangible index to the seasons.

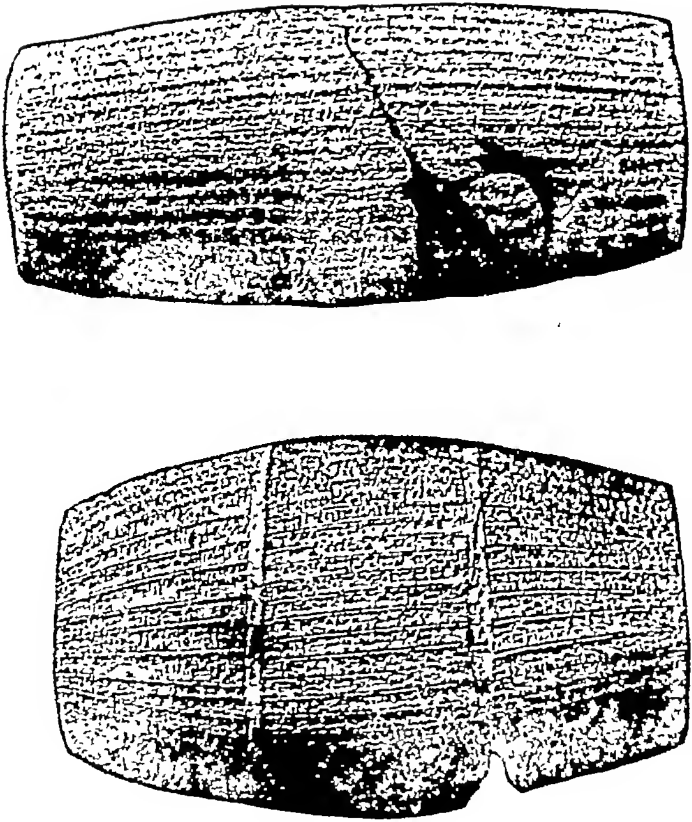
But in recognizing the time of the inundations and the vernal equinox, the Assyrians did not dethrone the moon from its accustomed precedence, for the year was reckoned as commencing not precisely at the vernal equinox, but at the new moon next before the equinox.

Beyond marking the seasons, the chief interests that actuated the Babylonian astronomer in his observations were astrological. After quoting Diodorus to the effect that the Babylonian priests observed the position of certain stars in order to cast horoscopes, Thompson tells us that from a very early day the very name Chaldean became synonymous with magician. He adds that

"from Mesopotamia, by way of Greece and Rome, a certain amount of Babylonian astrology made its way among the nations of the West, and it is quite probable that many superstitions which we commonly record as the peculiar product of western civilization took their origin from those of the early dwellers on the alluvial lands of Mesopotamia.

"One Assurbanipal, king of Assyria B.C. 668-626, added to the royal library at Nineveh his contribution of tablets, which included many series of documents which related exclusively to the astrology of the ancient Babylonians, who in turn had borrowed it with modifications from the Sumerian invaders of the country. Among these must be mentioned the series which was commonly called *The Day of Bel*, and which was decreed by the learned to have been written in the time of the great Sargon I, king of Agade, 3800 B.C.

"With such ancient works as these to guide them, the profession of deducing omens from daily events reached such a pitch of importance in the last Assyrian Empire that a system of making periodical reports came into being. By these the king was informed of all the occurrences in the heavens and on earth, and the results of astrological studies in respect to after events. The heads of the astrological profession were men of high rank and position, and their office was hereditary. The variety of information contained in these reports is best gathered from the fact that they were sent from cities as far removed from each other as Assur in the north and Erech in the south, and it can only be assumed that they were dispatched by runners, or men mounted on swift horses. As reports also came from Dilbat, Kutha, Nippur, and Bursippa, all cities of ancient foundation, the king was probably well



PERSIAN AND BABYLONIAN CYLINDERS
KINGS CYRUS AND NABONIDAS

acquainted with the general course of events in his empire."

From certain passages in the astrological tablets, Thompson draws the interesting conclusion that the Chaldean astronomers were acquainted with some kind of a machine for reckoning time He finds in one of the tablets a phrase which he interprets to mean measure-governor, and he infers from this the existence of a kind of a calculator. He calls attention also to the fact that Sextus Empiricus states that the clepsydra was known to the Chaldeans, and that Herodotus asserts that the Greeks borrowed certain measures of time from the Babylonians. He finds further corroboration in the fact that the Babylonians had a time-measure by which they divided the day and the night, a measure called kasbu, which contained two hours In a report relating to the day of the vernal equinox, it is stated that there are six kasbu of the day and six kasbu of the night.

While the astrologers deduced their omens from all the celestial bodies known to them, they chiefly gave attention to the moon, noting with great care the shape of its horns, and deducing such a conclusion as that "if the horns are pointed the king will overcome whatever he goreth," and that "when the moon is low at its appearance, the submission (of the people) of a far country will come"

The relations of the moon and sun were a source of constant observation, it being noted whether the sun and moon were seen together above the horizon; whether one set as the other rose, and the like. And whatever the phenomena, there was always, of course, a direct association between such phenomena and the well-being of humankind — in particular the king, at

whose instance, and doubtless at whose expense, the observations were carried out.

From omens associated with the heavenly bodies it is but a step to omens based upon other phenomena of nature, and we shall see in a moment that the Babylonian prophets made free use of their opportunities in this direction also. But before we turn from the field of astronomy, it will be well to inform ourselves as to what system the Chaldean astronomer had invented in explanation of the mechanics of the universe.

Our answer to this inquiry is not quite as definite as could be desired, the vagueness of the records, no doubt, coinciding with the like vagueness in the minds of the Chaldeans themselves. So far as we can interpret the somewhat mystical references that have come down to us, however, the Babylonian cosmology would seem to have represented the earth as a circular plane surrounded by a great circular river, beyond which rose an impregnable barrier of mountains, and resting upon an infinite sea of waters. The material vault of the heavens was supposed to find support upon the outlying circle of mountains. But the precise mechanism through which the observed revolution of the heavenly bodies was effected remains here, as with the Egyptian cosmology, somewhat conjectural.

The simple fact would appear to be that, for the Chaldeans as for the Egyptians, despite their most careful observations of the tangible phenomena of the heavens, no really satisfactory mechanical conception of the cosmos was attainable. We shall see in due course by what faltering steps the European imagination advanced from the crude ideas of Egypt and Babylonia to the relatively clear vision of Newton and Laplace.

We turn now from the field of the astrologer to the

closely allied province of Chaldean magic—a province which includes the other: which, indeed, is so all-encompassing as scarcely to leave any phase of Babylonian thought outside its bounds.

The tablets having to do with omens, exorcisms, and the like magic practises make up an astonishingly large proportion of the Babylonian records In viewing them it is hard to avoid the conclusion that the superstitions which they evidenced absolutely dominated the life of the Babylonians of every degree. Yet it must not be forgotten that the greatest inconsistencies everywhere exist between the superstitious beliefs of a people and the practical observances of that people. No other problem is so difficult for the historian as that which confronts him when he endeavors to penetrate the mysteries of an alien religion; and when, as in the present case, the superstitions involved have been transmitted from generation to generation, their exact practical phases as interpreted by any particular generation must be somewhat problematical.

The tablets upon which our knowledge of these omens is based are many of them from the libraries of the later kings of Nineveh; but the omens themselves are, in such cases, inscribed in the original Accadian form in which they have come down from remote ages, accompanied by an Assyrian translation. Thus the superstitions involved had back of them hundreds of years, even thousands of years, of precedent; and we need not doubt that the ideas with which they are associated were interwoven with almost every thought and deed of the life of the people.

Professor Sayce assures us that the Assyrians and Babylonians counted no fewer than three hundred spirits of heaven, and six hundred spirits of earth. "Like

CRETE: SCULPTURE — EXCAVATION
AT PALACE OF MINOS

the Jews of the Talmud," he says, "they believed that the world was swarming with noxious spirits, who produced the various diseases to which man is liable, and might be swallowed with the food and drink which support life." Fox Talbot was inclined to believe that exorcisms were the exclusive means used to drive away the tormenting spirits This seems unlikely, considering the uniform association of drugs with the magical practises among their people Yet there is certainly a strange silence of the tablets in regard to medicine

Talbot tells us that sometimes divine images were brought into the sick-chamber, and written texts taken from holy books were placed on the walls and bound around the sick man's members. If these failed, recourse was had to the influence of the mamit, which the evil powers were unable to resist On a tablet, written in the Accadian language only, the Assyrian version being taken, however, was found the following:

1. Take a white cloth. In it place the mamit,
2. in the sick man's right hand
3. Take a black cloth,
4. wrap it around his left hand
5. Then all the evil spirits (a long list of them is given)
6. and the sins which he has committed
7. shall quit their hold of him
8. and shall never return.

The symbolism of the black cloth in the left hand seems evident The dying man repents of his former evil deeds, and he puts his trust in holiness, symbolized by the white cloth in his right hand. Then follow some obscure lines about the spirits:

1. Their heads shall remove from his head.
2. Their hands shall let go his hands
3. Their feet shall depart from his feet.

Which perhaps may be explained thus: we learn from

another tablet that the various classes of evil spirits troubled different parts of the body; some injured the head, some the hands and the feet, etc., therefore the passage before may mean "the spirits whose power is over the hand shall loose their hands from his," etc "But," concludes Talbot, "I can offer no decided opinion upon such obscure points of their superstition"

In regard to evil spirits, as elsewhere, the number seven had a peculiar significance, it being held that that number of spirits might enter into a man together Talbot has translated a "wild chant" which he names "The Song of the Seven Spirits"

1 There are seven! There are seven!
2 In the depths of the ocean there are seven!
3. In the heights of the heaven there are seven!
4 In the ocean stream in a palace they were born
5 Male they are not: female they are not!
6. Wives they have not! Children are not born to them!
7. Rules they have not! Government they know not!
8 Prayers they hear not!
9 There are seven! There are seven! Twice over there are seven!

The tablets make frequent allusion to these seven spirits One starts thus:

1 The god (——) shall stand by his bedside,
2. These seven evil spirits he shall root out and shall expel them from his body,
3. and these seven shall never return to the sick man again

Altogether similar are the exorcisms intended to ward off disease. Professor Sayce has published translations of some of these. Each ends with the same phrase, and they differ only in regard to the particular maladies from which freedom is desired. One reads:

"From wasting, from want of health, from the evil spirit of the ulcer, from the spreading quinsy of the gullet, from the violent ulcer, from the noxious ulcer,

may the king of heaven preserve, may the king of earth preserve."

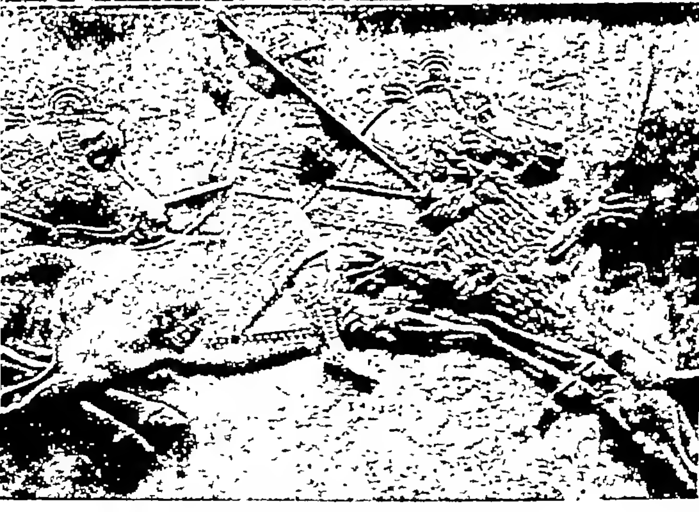
Another is phrased thus:

"From the cruel spirit of the head, from the strong spirit of the head, from the head spirit that departs not, from the head spirit that comes not forth, from the head spirit that will not go, from the noxious head spirit, may the king of heaven preserve, may the king of earth preserve."

As to omens having to do with the affairs of every-day life the number is legion. For example, Moppert has published, in the *Journal Asiatique*, the translation of a tablet which contains on its two sides several scores of birth-portents, a few of which may be quoted at random:

"When a woman bears a child and it has the ears of a lion, a strong king is in the country." "When a woman bears a child and it has a bird's beak, that country is oppressed" 'When a woman bears a child and its right hand is wanting, that country goes to destruction." "When a woman bears a child and its feet are wanting, the roads of the country are cut; that house is destroyed." "When a woman bears a child and at the time of its birth its beard is grown, floods are in the country."

It is interesting to recall that the observations of animate nature, which were doubtless superstitious in their motive, had given the Babylonians some inklings of a knowledge of classification. Thus, according to Menant, some of the tablets from Nineveh, which are written, as usual, in both Sumerian and Assyrian, and which therefore, like nearly all Assyrian books, draw upon the knowledge of old Babylonia, give lists of animals, making an attempt at classification.



A SACRIFICE TO BAAL — KING ASSURBANIPAL HUNTING

The dog, lion, and wolf are placed in one category; the ox, sheep, and goat in another; the dog family itself is divided into various races, as the domestic dog, the coursing dog, the small dog, the dog of Elan, etc.

Similar attempts at classification of birds are found. Thus, birds of rapid flight, sea-birds, and marsh-birds are differentiated. Insects are classified according to habit; those that attack plants, animals, clothing, or wood.

Vegetables seem to be classified according to their usefulness One tablet enumerates the uses of wood according to its adaptability for timber-work of palaces, or construction of vessels, the making of implements of husbandry, or even furniture. Minerals occupy a long series in these tablets. They are classed according to their qualities, gold and silver occupying a division apart; precious stones forming another series.

Our Babylonians, then, must be credited with the development of a rudimentary science of natural history

Medical practise in the Babylonian world was strangely under the cloud of superstition. It is known, however, that the practitioner of medicine occupied a position of some authority and responsibility. The proof of this is found in the clauses relating to the legal status of the physician which are contained in the now famous code of the Babylonian King Hammurabi, who reigned about 2300 years before our era These clauses, tho throwing no light on the scientific attainments of the physician of the period, are too curious to be omitted They are clauses 215 to 227 of the celebrated code, and are as follows:

215. If a doctor has treated a man for a severe wound with a lancet of bronze and has cured the man, or has opened a tumor with a bronze lancet and has cured the man's eye, he shall receive ten shekels of silver.

216. If it was a freedman, he shall receive five shekels of silver.

217. If it was a man's slave, the owner of the slave shall give the doctor two shekels of silver.

218. If a physician has treated a free-born man for a severe wound with a lancet of bronze and has caused the man to die, or has opened a tumor of the man with a lancet of bronze and has destroyed his eye, his hands one shall cut off.

219 If the doctor has treated the slave of a freedman for a severe wound with a bronze lancet and has caused him to die, he shall give back slave for slave

220. If he has opened his tumor with a bronze lancet and has ruined his eye, he shall pay the half of his price in money

221. If a doctor has cured the broken limb of a man, or has healed his sick body, the patient shall pay the doctor five shekels of silver

222 If it was a freedman, he shall give three shekels of silver

223. If it was a man's slave, the owner of the slave shall give two shekels of silver to the doctor.

224. If the doctor of oxen and asses has treated an ox or an ass for a grave wound and has cured it, the owner of the ox or the ass shall give to the doctor as his pay one-sixth of a shekel of silver.

225. If he has treated an ox or an ass for a severe wound and has caused its death, he shall pay one-fourth of its price to the owner of the ox or the ass

226. If a barber-surgeon, without consent of the owner of a slave, has branded the slave with an indelible mark, one shall cut off the hands of that barber

227. If any one deceive the surgeon-barber and make him brand a slave with an indelible mark, one shall kill that man and bury him in his house The barber shall swear, "I did not mark him wittingly," and he shall be guiltless

Before turning from the Oriental world it is perhaps worth while to attempt to estimate somewhat specifically the world-influence of the name, Babylonian science. Perhaps we cannot better gain an idea as to the

estimate put upon that science by the classical world than through a somewhat extended quotation from a classical author. Diodorus Siculus, who, as already noted, lived at about the time of Augustus, and who, therefore, scanned in perspective the entire sweep of classical Greek history, has left us a striking summary which is doubly valuable because of its comparisons of Babylonian with Greek influence. Having viewed the science of Babylonia in the light of the interpretations made possible by the recent study of original documents, we are prepared to draw our own conclusions from the statements of the Greek historian Here is his estimate in the words of the quaint translation made by Philemon Holland in the year 1700:

"They being the most ancient Babylonians, hold the same station and dignity in the Common-wealth as the Egyptian Priests do in Egypt: For being deputed to Divine Offices, they spend all their Time in the study of Philosophy, and are especially famous for the Art of Astrology They are mightily given to Divination, and foretel future Events, and imploy themselves either by Purifications, Sacrifices, or other Inchantments to avert Evils, or procure good Fortune and Success. They are skilful likewise in the Art of Divination, by the flying of Birds, and interpreting of Dreams and Prodigies: And are reputed as true Oracles (in declaring what will come to pass) by their exact and diligent viewing the Intrals of the Sacrifices But they attain not to this Knowledge in the same manner as the Grecians do; for the Chaldeans learn it by Tradition from their Ancestors, the Son from the Father, who are all in the mean time free from all other publick Offices and Attendances; and because their Parents are their Tutors, they both learn every thing without Envy, and

rely with more confidence upon the truth of what is taught them; and being train'd up in this Learning from their very Childhood, they become most famous Philosophers (that Age being most capable of Learning, wherein they spend much of their time).

"From a long observation of the Stars, and an exact Knowledge of the motions and influences of every one of them, wherein they excel all others, they fortel many things that are to come to pass

"They say that the Five Stars which some call Planets, but they Interpreters, are most worthy of Consideration, both for their motions and their remarkable influences, especially that which the Grecians call Saturn The brightest of them all, and which often portends many and great Events, they call Sol, the other Four they name Mars, Venus, Mercury, and Jupiter, with our own Country Astrologers They give the Name of Interpreters to these Stars, because these only by a peculiar Motion do portend things to come, and instead of Jupiters, do declare to Men before-hand the good-will of the Gods; whereas the other Stars (not being of the number of the Planets) have a constant ordinary motion Future Events (they say) are pointed at sometimes by their Rising, and sometimes by their Setting, and at other times by their Colour, as may be experienc'd by those that will diligently observe it; sometimes foreshewing Hurricanes, at other times Tempestuous Rains, and then again exceeding Droughts.

By these, they say, are often portended the appearance of Comets, Eclipses of the Sun and Moon, Earthquakes and all other the various Changes and remarkable effects in the Air, boding good and bad, not only to Nations in general, but to Kings and Private Persons in particular.

"Through Twelve Signs the Sun, Moon, and the other Five Planets run their Course. The Sun in a Years time, and the Moon in the space of a Month To every one of the Planets they assign their own proper Courses, which are perform'd variously in lesser or shorter time according as their several motions are quicker or slower. These Stars, they say, have a great influence both as to good and bad in Mens Nativities; and from the consideration of their several Natures, may be foreknown what will befal Men afterwards. As they foretold things to come to other Kings formerly, so they did to Alexander who conquer'd Darius, and to his Successors Antigonus and Seleucus Nicator; and accordingly things fell out as they declar'd.

"They tell likewise private Men their Fortunes so certainly, that those who have found the thing true by Experience, have esteem'd it a Miracle, and above the reach of man to perform. Out of the Circle of the Zodiack they describe Four and Twenty Stars, Twelve towards the North Pole, and as many to the South.

"Those which we see, they assign to the living, and the other that do not appear, they conceive are Constellations for the Dead; and they term them Judges of all things. The Moon, they say, is in the lowest Orb, and being therefore next to the Earth (because she is so small), she finishes her Course in a little time, not through the swiftness of her Motion, but the shortness of her Sphear. In that which they affirm (that she has but a borrow'd light, and that when she is eclips'd, it's caus'd by the interposition of the shadow of the Earth) they agree with the Grecians.

"Their Rules and Notions concerning the Eclipses of the Sun are but weak and mean, which they dare not positively foretel, nor fix a certain time for them. They

have likewise Opinions concerning the Earth peculiar to themselves, affirming it to resemble a Boat, and to be hollow, to prove which, and other things relating to the frame of the World, they abound in Arguments. But this any Man may justly and truly say, that the Chaldeans far exceed all other Men in the Knowledge of Astrology, and have study'd it most of any other Art or Science: But the number of years during which the Chaldeans say, those of their Profession have given themselves to the study of this natural Philosophy, is incredible; for when Alexander was in Asia, they reckon'd up Four Hundred and Seventy Thousand Years since they first began to observe the Motions of the Stars."

Let us now supplement this estimate of Babylonian influence, with another estimate written in our own day,—that of Canon Rawlinson in his *Great Oriental Monarchies.* Of Babylonia he says:

"Hers was apparently the genius which excogitated an alphabet; worked out the simpler problems of arithmetic; invented implements for measuring the lapse of time; conceived the idea of raising enormous structures with the poorest of all materials, clay; discovered the art of polishing, boring, and engraving gems; reproduced with truthfulness the outlines of human and animal forms; attained to high perfection in textile fabrics; studied with success the motions of the heavenly bodies; conceived of grammar as a science; elaborated a system of law; saw the value of an exact chronology—in almost every branch of science made a beginning, thus rendering it comparatively easy for other nations to proceed with the superstructure. . . .

"It was from the East, not from Egypt, that Greece derived her architecture, her sculpture, her science, her

philosophy, her mathematical knowledge—in a word, her intellectual life. And Babylon was the source to which the entire stream of Eastern civilization may be traced. It is scarcely too much to say that, but for Babylon, real civilization might not yet have dawned upon the earth."

Considering that a period of almost two thousand years separates the times of writing of these two estimates, the estimates themselves are singularly in unison They show that the greatest of Oriental nations has not suffered in reputation at the hands of posterity.

It is indeed almost impossible to contemplate the monuments of Babylonian and Assyrian civilization that are now preserved in the European and American museums without becoming enthusiastic. That certainly was a wonderful civilization which has left us the tablets on which are inscribed the laws of a Hammurabi on the one hand, and the art treasures of the palace of an Asshurbanipal on the other.

Yet a candid consideration of the scientific attainments of the Babylonians and Assyrians can scarcely arouse us to a like enthusiasm. So far as pure science is concerned, the efforts of the Babylonians and Assyrians chiefly centered about the subjects of astrology and magic.

With the records of their ghost-haunted science fresh in mind, one might be forgiven for a momentary desire to take issue with Canon Rawlinson's words. We are assured that the scientific attainments of Europe are almost solely to be credited to Babylonia and not to Egypt, but we should not forget that Plato, the greatest of the Greek thinkers, went to Egypt and not to Babylonia to pursue his studies when he wished to penetrate the secrets of Oriental science and philosophy.

Clearly, then, classical Greece did not consider Babylonia as having a monopoly of scientific knowledge, and we of today, when we attempt to weigh the new evidence that has come to us in recent generations with the Babylonian records themselves, find that some, at least, of the heritages for which Babylonia has been praised are of more than doubtful value.

Babylonia, for example, gave us our seven-day week and our system of computing by twelves. But surely the world could have got on as well without that magic number seven, and after some hundreds of generations we are coming to feel that the decimal system of the Egyptians has advantages over the duodecimal system of the Babylonians.

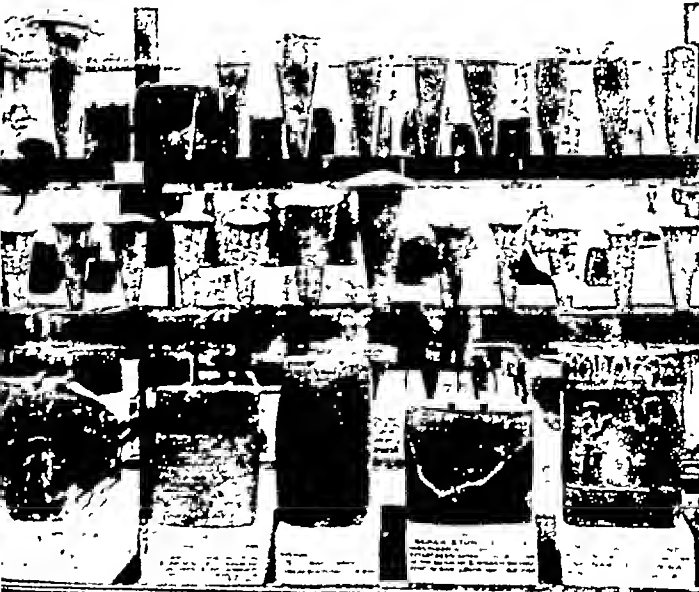
Again, the Babylonians did not invent the alphabet; they did not even accept it when all the rest of the world had recognized its value. In grammar and arithmetic, as with astronomy, they seem not to have advanced greatly, if at all, upon the Egyptians.

One field in which they stand out in startling preeminence is the field of astrology; but this, in the estimate of modern thought, is the very negation of science. Babylonia impressed her superstitions on the Western world, and when we consider the baleful influence of these superstitions, we may almost question whether we might not reverse Canon Rawlinson's estimate and say that perhaps but for Babylonia real civilization, based on the application of true science, might have dawned upon the earth a score of centuries before it did.

Yet, after all, perhaps this estimate is unjust. Society, like an individual organism, must creep before it can walk, and perhaps the Babylonian experiments in astrology and magic, which European civilization was destined to copy for some three or four thousand years,

must have been made a part of the necessary evolution of our race in one place or in another.

That thought, however, need not blind us to the essential fact, which the historian of science must needs admit, that for the Babylonian, despite his boasted culture, science spelled superstition.



BABYLONIAN INSCRIPTIONS

THE ROSETTA STONE IN THE BRITISH MUSEUM

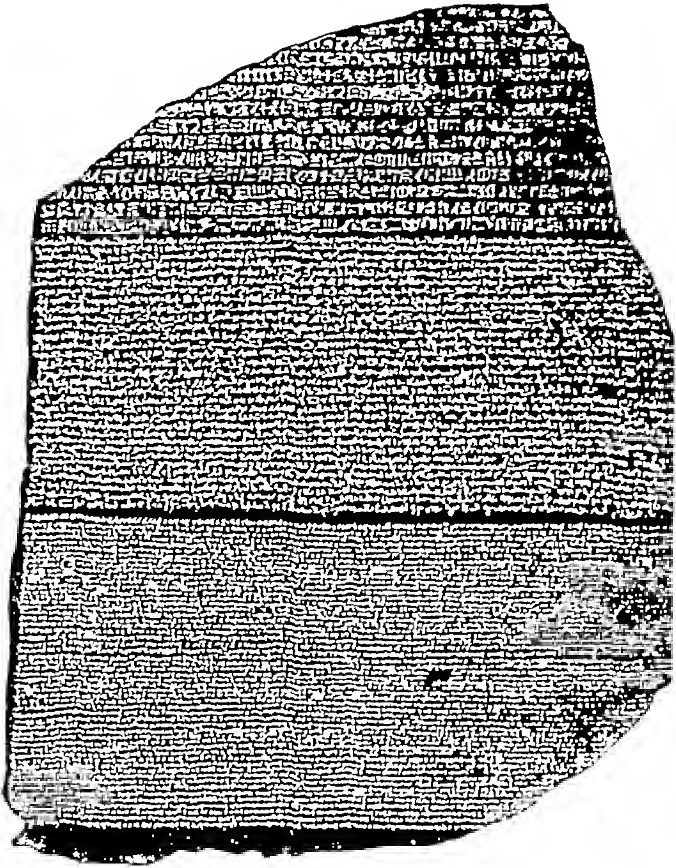
IV

THE DEVELOPMENT OF THE ALPHABET

BEFORE we turn specifically to the new world of the west, it remains to take note of what may perhaps be regarded as the very greatest achievement of ancient science. This was the analysis of speech sounds, and the resulting development of a system of alphabetical writing. To comprehend the series of scientific inductions which led to this result, we must go back in imagination and trace briefly the development of the methods of recording thought by means of graphic symbols. In other words, we must trace the evolution of the art of writing. In doing so we cannot hold to national lines as we have done in the preceding two chapters, tho the efforts of the two great scientific nations just considered will enter prominently into the story.

The familiar Greek legend assures us that a Phenician named Kadmus was the first to bring a knowledge of letters into Europe. An elaboration of the story, current throughout classical times, offered the further explanation that the Phenicians had in turn acquired the art of writing from the Egyptians or Babylonians. Knowledge as to the true origin and development of the art of writing did not extend in antiquity beyond such vagaries as these. Nineteenth-century studies gave the first real clues to an understanding of the subject.

These studies tended to authenticate the essential fact on which the legend of Kadmus was founded; to the extent, at least, of making it probable that the later

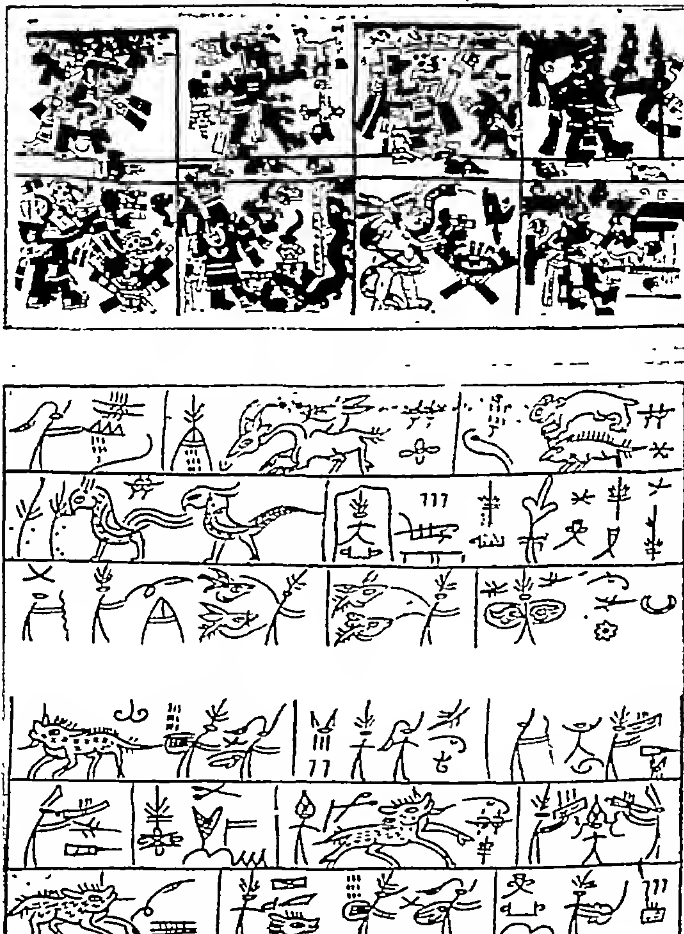


THE ROSETTA STONE· INSCRIPTIONS IN HIEROGLYPHICS, HIERATIC, AND GREEK

Grecian alphabet was introduced from Phenicia—tho not, of course, by any individual named Kadmus, the latter being, indeed, a name of purely Greek origin Further studies of the past generation tended to corroborate the ancient belief as to the original source of the Phenician alphabet, but divided scholars between two opinions: the one contending that the Egyptian hieroglyphics were the source upon which the Phenicians drew; and the other contending with equal fervor that the Babylonian wedge character must be conceded that honor.

But, as has often happened in other fields after years of acrimonious controversy, a new discovery or two may suffice to show that neither contestant was right. After the Egyptologists of the school of De Rougé thought they had demonstrated that the familiar symbols of the Phenician alphabet had been copied from that modified form of Egyptian hieroglyphics known as the hieratic writing, the Assyriologists came forward to prove that certain characters of the Babylonian syllabary also show a likeness to the alphabetical characters that seemingly could not be due to chance. And then, when a settlement of the dispute seemed almost hopeless, it was shown through the Egyptian excavations that characters even more closely resembling those in dispute had been in use all about the shores of the Mediterranean, quite independently of either Egyptian or Assyrian writings, from periods so ancient as to be virtually prehistoric.

Coupled with this disconcerting discovery are the revelations brought to light by the excavations at the sites of Knossos and other long-buried cities of the island of Crete. These excavations, which are still in progress, show that the art of writing was known and



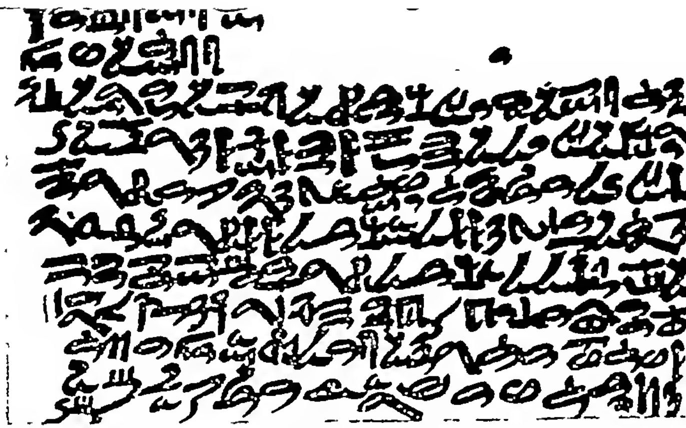
MEXICAN (MAYAN) AND CHINESE
PICTURE WRITING

practised independently in Crete before that cataclysmic overthrow of the early Greek civilization which archeologists are accustomed to ascribe to the hypothetical invasion of the Dorians.

The significance of this is that the art of writing was known in Europe long before the advent of the mythical Kadmus But since the early Cretan scripts are not to be identified with the scripts used in Greece in historical times, whereas the latter are undoubtedly of lineal descent from the Phenician alphabet, the validity of the Kadmus legend, in a modified form, must still be admitted.

As has just been suggested, the new knowledge, particularly that which related to the great antiquity of characters similar to the Phenician alphabetical signs, is somewhat disconcerting. Its general trend, however, is quite in the same direction with most of the new archeological knowledge of recent decades—that is to say, it tends to emphasize the idea that human civilization in most of its important elaborations is vastly older than has hitherto been supposed. It may be added, however, that no definite clues are as yet available that enable us to fix even an approximate date for the origin of the Phenician alphabet. The signs, to which reference has been made, may well have been in existence for thousands of years, utilized merely as property marks, symbols for counting and the like, before the idea of setting them aside as phonetic symbols was ever conceived

Nothing is more certain, in the judgment of the present-day investigator, than that man learned to write by slow and painful stages. It is probable that the conception of such an analysis of speech sounds as would make the idea of an alphabet possible came at a very late stage of social evolution, and as the culminating



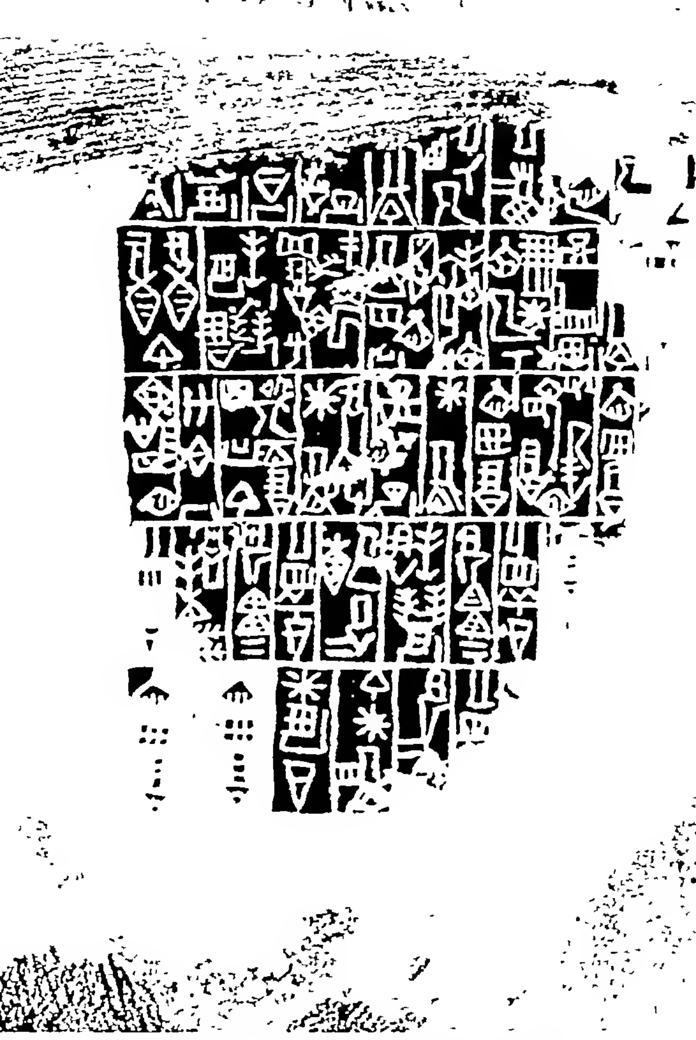
THE EGYPTIAN PRISSE PAPYRUS —
EGYPTIAN BAS-RELIEF

achievement of a long series of improvements in the art of writing. The precise steps that marked this path of intellectual development can for the most part be known only by inference; yet it is probable that the main chapters of the story may be reproduced with essential accuracy

For the very first chapters of the story we must go back in imagination to the prehistoric period

Even barbaric man feels the need of self-expression, and strives to make his ideas manifest to other men by pictorial signs. The cave-dweller scratched pictures of men and animals on the surface of a reindeer horn or mammoth tusk as mementos of his prowess. The American Indian does essentially the same thing today, making pictures that crudely record his successes in war and the chase. The Northern Indian had got no farther than this when the white man discovered America; but the Aztecs of the Southwest and the Maya people of Yucatan had carried their picture-making to a much higher state of elaboration. They had developed systems of pictographs or hieroglyphics that would doubtless in the course of generations have been elaborated into alphabetical systems, had not the Europeans cut off the civilization of which they were the highest exponents.

What the Aztec and Maya were striving toward in the sixteenth century A D., various Oriental nations had attained at least five or six thousand years earlier. In Egypt at the time of the pyramid-builders, and in Babylonia at the same epoch, the people had developed systems of writing that enabled them not merely to present a limited range of ideas pictorially, but to express in full elaboration and with finer shades of meaning all the ideas that pertain to highly cultured existence. The man of that time made records of mili-



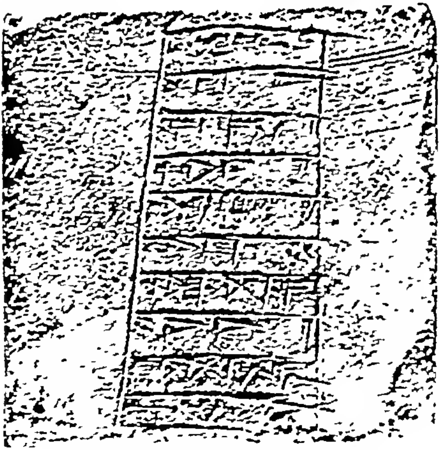
EARLY BABYLONIAN INSCRIPTION

tary achievements, recorded the transactions of everyday business life, and gave expression to his moral and spiritual aspirations in a way strangely comparable to the manner of our own time. He had perfected highly elaborate systems of writing.

Of the two ancient systems of writing just referred to as being in vogue at the so-called dawnings of history, the more picturesque and suggestive was the hieroglyphic system of the Egyptians.

This is a curiously conglomerate system of writing, made up in part of symbols reminiscent of the crudest stages of picture-writing, in part of symbols having the phonetic value of syllables, and in part of true alphabetical letters. In a word, the Egyptian writing represents in itself the elements of the various stages through which the art of writing has developed. We must conceive that new features were from time to time added, while the old, curiously enough, were not given up.

Here, for example, in the midst of unintelligible lines and pot-hooks, are various pictures that are instantly recognizable as representations of hawks, lions, ibises, and the like. It can hardly be questioned that when these pictures were first used calligraphically they were meant to represent the idea of a bird or animal. In other words, the first stage of picture-writing did not go beyond the mere representation of an eagle by the picture of an eagle. But this, obviously, would confine the presentation of ideas within very narrow limits. In due course some inventive genius conceived the thought of symbolizing a picture. To him the outline of an eagle might represent not merely an actual bird, but the thought of strength, of courage, or of swift progress. Such a use of symbols obviously extends the range of utility of a nascent art of writing.



BABYLONIAN TABLETS

Then in due course some wonderful psychologist—or perhaps the joint efforts of many generations of psychologists—made the astounding discovery that the human voice, which seems to flow on in an unbroken stream of endlessly varied modulations and intonations, may really be analyzed into a comparatively limited number of component sounds—into a few hundreds of syllables. That wonderful idea conceived, it was only a matter of time until it would occur to some other enterprising genius that by selecting an arbitrary symbol to represent each one of these elementary sounds it would be possible to make a written record of the words of human speech which could be reproduced—rephonated—by some one who had never heard the words and did not know in advance what this written record contained.

This, of course, is what every child learns to do now in the primer class, but we may feel assured that such an idea never occurred to any human being until the peculiar forms of pictographic writing just referred to had been practised for many centuries. Yet, as we have said, some genius of prehistoric Egypt conceived the idea and put it into practical execution, and the hieroglyphic writing of which the Egyptians were in full possession at the very beginning of what we term the historical period made use of this phonetic system along with the ideographic system already described.

So fond were the Egyptians of their pictorial symbols used ideographically that they clung to them persistently throughout the entire period of Egyptian history. They used symbols as phonetic equivalents very frequently, but they never learned to depend upon them exclusively. The scribe always interspersed his phonetic signs with some other signs intended as graphic

EGYPTIAN-ARAMAIC STELE OF THIRD CENTURY B C

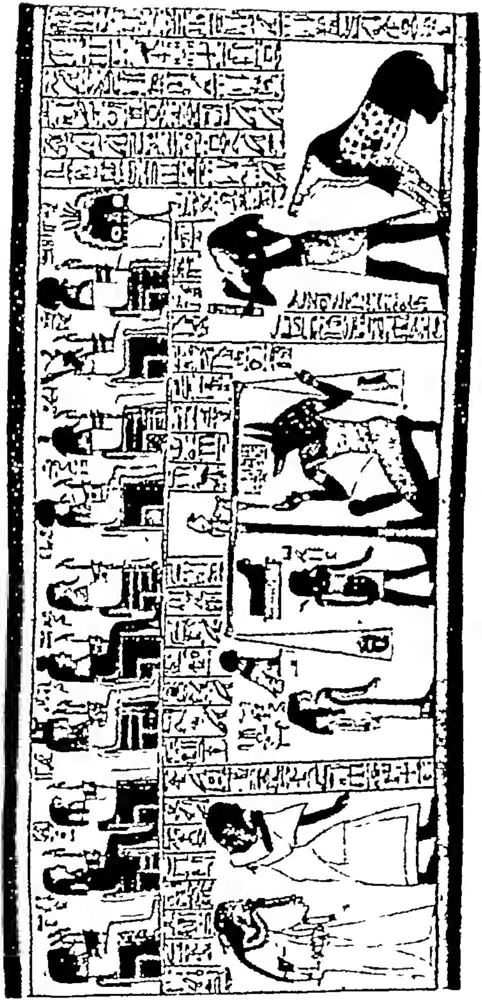
aids. After spelling a word out in full, he added a picture, sometimes even two or three pictures, representative of the individual thing, or at least of the type of thing to which the word belongs. Two or three illustrations will make this clear.

Thus *geften*, monkey, is spelled out in full, but the picture of a monkey is added as a determinative; second, *genu*, cavalry, after being spelled, is made unequivocal by the introduction of a picture of a horse; third, *temati*, wings, tho spelled elaborately, has pictures of wings added; and fourth, *tatu*, quadrupeds, after being spelled, has a picture of a quadruped, and then the picture of a hide, which is the usual determinative of a quadruped, followed by three dashes to indicate the plural number.

It must not be supposed, however, that it was a mere whim which led the Egyptians to the use of this system of determinatives. There was sound reason back of it. It amounted to no more than the expedient we adopt when we spell "to," "two," or "too," in indication of a single sound with three different meanings. The Egyptian language abounds in words having more than one meaning, and in writing these it is obvious that some means of distinction is desirable.

The same thing occurs even more frequently in the Chinese language, which is monosyllabic. The Chinese adopt a more clumsy expedient, supplying a different symbol for each of the meanings of a syllable; so that while the actual word-sounds of their speech are only a few hundreds in number, the characters of their written language mount high into the thousands.

While the civilization of the Nile Valley was developing this extraordinary system of hieroglyphics, the inhabitants of Babylonia were practising the art of writ-



THE EGYPTIAN BOOK OF THE DEAD

ing along somewhat different lines. It is certain that they began with picture-making, and that in due course they advanced to the development of the syllabary, but, unlike their Egyptian cousins, the men of Babylonia saw fit to discard the old system when they had perfected a better one. So at a very early day their writing—as revealed to us now through the recent excavations—had ceased to have that pictorial aspect which distinguishes the Egyptian script. What had originally been pictures of objects—fish, houses, and the like—had come to be represented by mere aggregations of wedge-shaped marks.

As the writing of the Babylonians was chiefly inscribed on soft clay, the adaptation of this wedge-shaped mark in lieu of an ordinary line was probably a mere matter of convenience, since the sharp-cornered implement used in making the inscription naturally made a wedge-shaped impression in the clay. That, however, is a detail. The essential thing is that the Babylonian had so fully analyzed the speech-sounds that he felt entire confidence in them, and having selected a sufficient number of conventional characters—each made up of wedge-shaped lines—to represent all the phonetic sounds of his language, spelled the words out in syllables and to some extent dispensed with the determinative signs which, as we have seen, played so prominent a part in the Egyptian writing.

His cousins the Assyrians used habitually a system of writing the foundation of which was an elaborate phonetic syllabary; a system, therefore, far removed from the old crude pictograph, and in some respects much more developed than the complicated Egyptian method; yet a system that stopped short of perfection by the wide gap that separates the syllabary from the true alphabet.

BAKED CLAY ASSYRIAN TABLET.

A brief analysis of speech sounds will aid us in understanding the real nature of the syllabary. Let us take for consideration the consonantal sound represented by the letter *b*. A moment's consideration will make it clear that this sound enters into a large number of syllables. There are, for example, at least twenty vowel sounds in the English language, not to speak of certain digraphs; that is to say, each of the important vowels has from two to six sounds Each of these vowel sounds may enter into combination with the *b* sounds alone to form three syllables; as ba, ab, bal, be, eb, bel, etc Thus there are at least sixty *b*-sound syllables. But this is not the end, for other consonantal sounds may be associated in the syllables in such combinations as bad, bed, bar, bark, cab, etc As each of the other twenty odd consonantal sounds may enter into similar combinations, it is obvious that there are several hundreds of fundamental syllables to be taken into account in any syllabic system of writing.

For each of these syllables a symbol must be set aside and held in reserve as the representative of that particular sound. A perfect syllabary, then, would require some hundred or more of symbols to represent *b* sounds alone; and since the sounds for *c*, *d*, *f*, and the rest are equally varied, the entire syllabary would run into thousands of characters, almost rivaling in complexity the Chinese system.

But in practise the most perfect syllabary, such as that of the Babylonians, fell short of this degree of precision through ignoring the minor shades of sound; just as our own alphabet is content to represent some thirty vowel sounds by five letters, ignoring the fact that *a*, for example, has really half a dozen distinct phonetic values. By such slurring of sounds the syllabary is re-

duced far below its ideal limits; yet even so it retains three or four hundred characters.

In point of fact, such a work as Professor Delitzsch's *Assyrian Grammar* presents signs for three hundred and thirty-four syllables, together with sundry alternative signs and determinatives to tax the memory of the would-be reader of Assyrian. Let us take for example a few of the *b* sounds It has been explained that the basis of the Assyrian written character is a simple wedge-shaped or arrow-head mark Variously repeated and grouped, these marks make up the syllabic characters.

To learn some four hundred such signs as these was the task set, as an equivalent of learning the a b c's, to any primer class in old Assyria in the long generations when that land was the culture center of the world Nor was the task confined to the natives of Babylonia and Assyria alone. About the fifteenth century B C., and probably for a long time before and after that period, the exceedingly complex syllabary of the Babylonians was the official means of communication throughout western Asia and between Asia and Egypt, as we know from the chance discovery of a collection of letters belonging to the Egyptian king Khun-aten, preserved at Tel-el-Amarna. In the time of Ramses the Great the Babylonian writing was in all probability considered by a majority of the most highly civilized people in the world to be the most perfect script practicable. Doubtless the average scribe of the time did not in the least realize the waste of energy involved in his labors, or ever suspect that there could be any better way of writing.

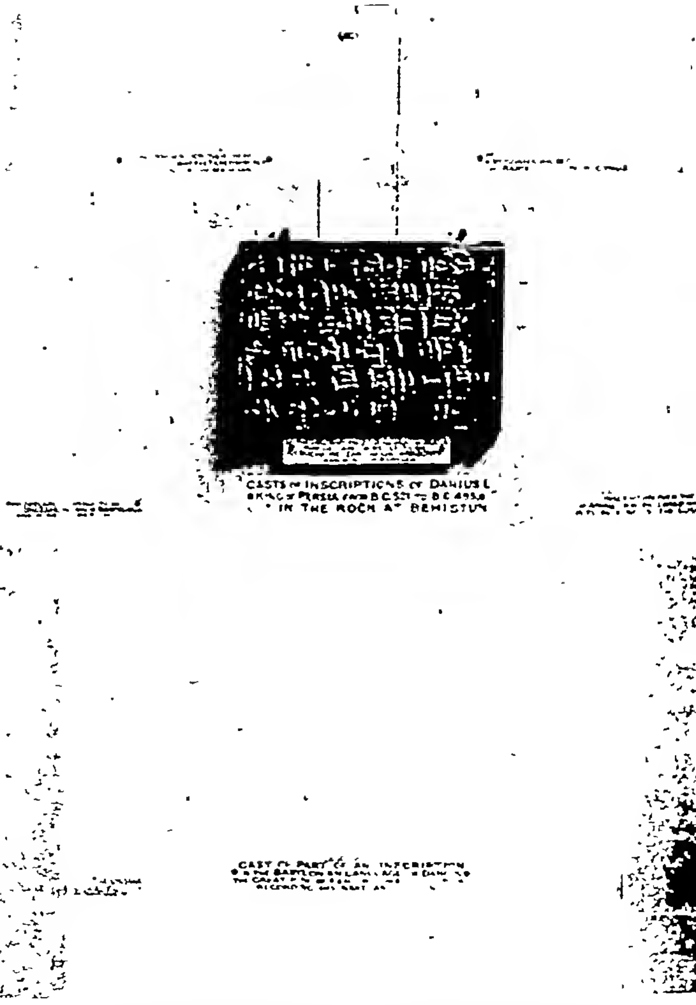
Yet the analysis of any one of these hundreds of syllables into its component phonetic elements — had any one been genius enough to make such analysis

would have given the key to simpler and better things But such an analysis was very hard to make, as the sequel shows Nor is the utility of such an analysis self-evident, as the experience of the Egyptians proved. The vowel sound is so intimately linked with the consonant —the *con*-sonant, implying this intimate relation in its very name—that it seemed extremely difficult to give it individual recognition. To set off the mere labial beginning of the sound by itself, and to recognize it as an all-essential element of phonation, was the feat at which human intelligence so long balked

The germ of great things lay in that analysis. It was a process of simplification, and all art development is from the complex to the simple. Unfortunately, however, it did not seem a simplification, but rather quite the reverse. We may well suppose that the idea of wresting from the syllabary its secret of consonants and vowels, and giving to each consonantal sound a distinct sign, seemed a most cumbersome and embarrassing complication to the ancient scholars—that is to say, after the time arrived when any one gave such an idea expression.

We can imagine them saying: "You will oblige us to use four signs instead of one to write such an elementary syllable as 'bard,' for example. Out upon such endless perplexity!" Nor is such a suggestion purely gratuitous, for it is an historical fact that the old syllabary continued to be used in Babylon hundreds of years after the alphabetical system had been introduced. Custom is everything in establishing our prejudices. The Japanese today rebel against the introduction of an alphabet, thinking it ambiguous

Yet, in the end, conservatism always yields, and so it was with opposition to the alphabet. Once the idea



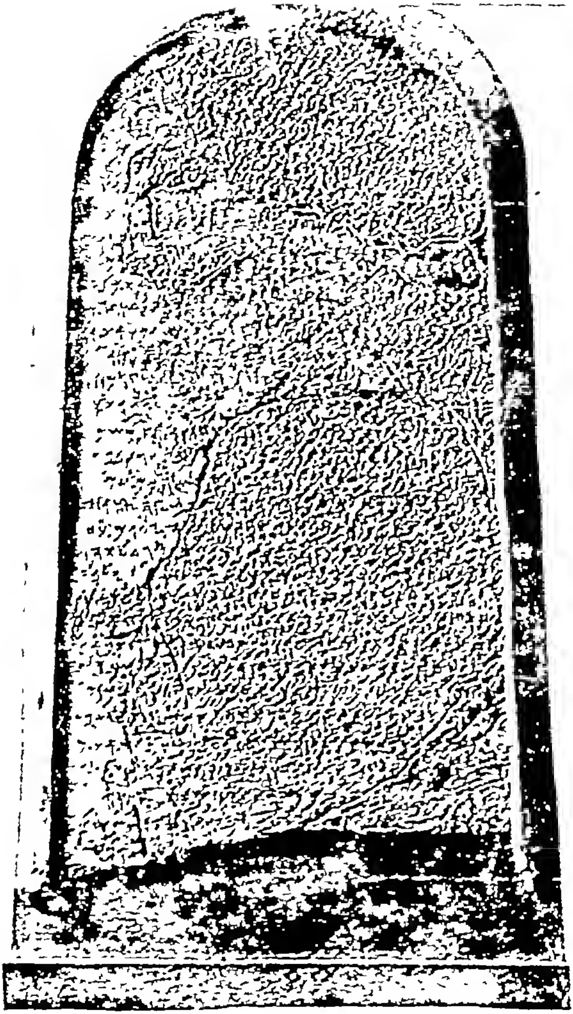
INSCRIPTIONS OF KING DARIUS ON ROCK OF BEHISTUN, FIFTH CENTURY B.C.

of the consonant had been firmly grasped, the old syllabary was doomed, tho generations of time might be required to complete the obsequies—generations of time and the influence of a new nation We have now to inquire how and by whom this advance was made

We cannot believe that any nation could have vaulted to the final stage of the simple alphabetical writing without tracing the devious and difficult way of the pictograph and the syllabary. It is possible, however, for a cultivated nation to build upon the shoulders of its neighbors, and, profiting by the experience of others, to make sudden leaps upward and onward. And this is seemingly what happened in the final development of the art of writing. For while the Babylonians and Assyrians rested content with their elaborate syllabary, a nation on either side of them, geographically speaking, solved the problem, which they perhaps did not even recognize as a problem; wrested from their syllabary its secret of consonants and vowels, and by adopting an arbitrary sign for each consonantal sound, produced that most wonderful of human inventions, the alphabet.

The two nations credited with this wonderful achievement are the Phenicians and the Persians. But it is not usually conceded that the two are entitled to anything like equal credit. The Persians, probably in the time of Cyrus the Great, used certain characters of the Babylonian script for the construction of an alphabet; but at this time the Phenician alphabet had undoubtedly been in use for some centuries, and it is more than probable that the Persian borrowed his idea of an alphabet from a Phenician source. And that, of course, makes all the difference.

Granted the idea of an alphabet, it requires no great reach of constructive genius to supply a set of alpha-



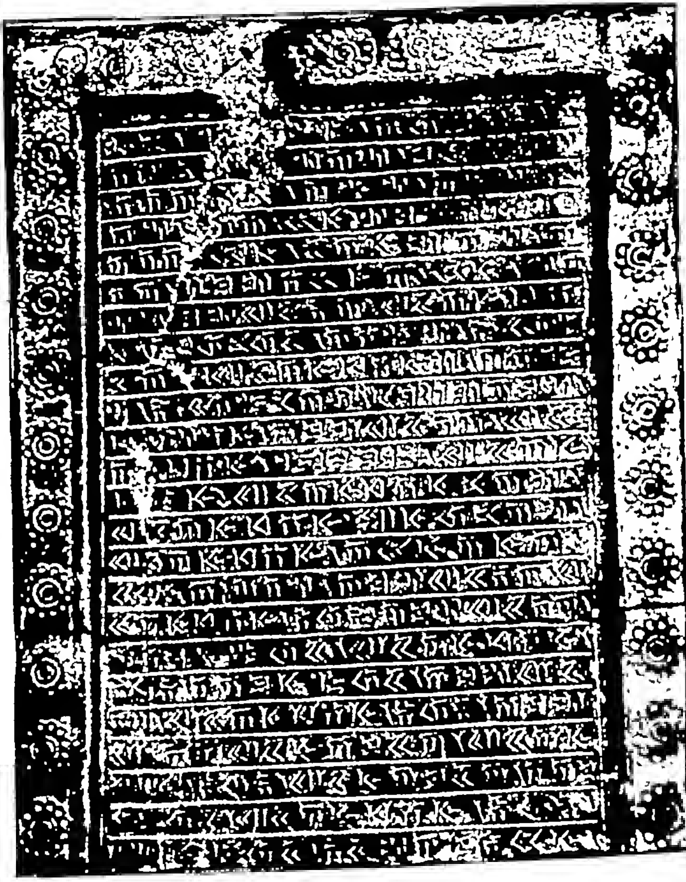
THE MOABITE STONE — EARLIEST PHENICIAN CHARACTERS

betical characters; tho even here, it may be added parenthetically, a study of the development of alphabets will show that mankind has all along had a characteristic propensity to copy rather than to invent

Regarding the Persian alphabet-maker, then, as a copyist rather than a true inventor, it remains to turn attention to the Phenician source whence, as is commonly believed, the original alphabet which became "the mother of all existing alphabets" came into being. It must be admitted at the outset that evidence for the Phenician origin of this alphabet is traditional rather than demonstrative. The Phenicians were the great traders of antiquity; undoubtedly they were largely responsible for the transmission of the alphabet from one part of the world to another, once it had been invented. Too much credit cannot be given them for this; and as the world always honors him who makes an idea fertile rather than the originator of the idea, there can be little injustice in continuing to speak of the Phenicians as the inventors of the alphabet. But the actual facts of the case will probably never be known.

For aught we know, it may have been some dreamy-eyed Israelite, some Babylonian philosopher, some Egyptian mystic, perhaps even some obscure Cretan, who gave to the hard-headed Phenician trader this conception of a dismembered syllable with its all-essential, elemental, wonder-working consonant. But it is futile now to attempt even to surmise on such unfathomable details as these.

Suffice it that the analysis was made; that one sign and no more was adopted for each consonantal sound of the Semitic tongue, and that the entire cumbersome mechanism of the Egyptian and Babylonian writing systems was rendered obsolescent. These systems did not



PERSIAN INSCRIPTION OF ARTAXERXES III

yield at once, to be sure; all human experience would have been set at naught had they done so. They held their own, and much more than held their own, for many centuries After the Phenicians as a nation had ceased to have importance; after their original script had been endlessly modified by many alien nations; after the original alphabet had made the conquest of all civilized Europe and of far outlying portions of the Orient—the Egyptian and Babylonian scribes continued to indite their missives in the same old pictographs and syllables

The inventive thinker must have been struck with amazement when, after making the fullest analysis of speech-sounds of which he was capable, he found himself supplied with only a score or so of symbols Yet as regards the consonantal sounds he had exhausted the resources of the Semitic tongue. As to vowels, he scarcely considered them at all. It seemed to him sufficient to use one symbol for each consonantal sound. This reduced the hitherto complex mechanism of writing to so simple a system that the inventor must have regarded it with sheer delight.

On the other hand, the conservative scholar doubtless thought it distinctly ambiguous. In truth, it must be admitted that the system was imperfect. It was a vast improvement on the old syllabary, but it had its drawbacks Perhaps it had been made a bit too simple; certainly it should have had symbols for the vowel sounds as well as for the consonants. Nevertheless, the vowel-lacking alphabet seems to have taken the popular fancy, and to this day Semitic people have never supplied its deficiencies save with certain dots and points.

Peoples using the Aryan speech soon saw the defect, and the Greeks supplied symbols for several new sounds at a very early day. But there the matter rested,

RUINS AT PERSEPOLIS

and the alphabet has remained imperfect For the purposes of the English language there should certainly have been added a dozen or more new characters. It is clear, for example, that, in the interest of explicitness, we should have a separate symbol for the vowel sound in each of the following syllables: bar, bay, bann, ball, to cite a single illustration

There is, to be sure, a seemingly valid reason for not extending our alphabet, in the fact that in multiplying syllables it would be difficult to select characters at once easy to make and unambiguous. Moreover, the conservatives might point out, with telling effect, that the present alphabet has proved admirably effective for about three thousand years. Yet the fact that our dictionaries supply diacritical marks for some thirty vowel sounds to indicate the pronunciation of the words of our every-day speech, shows how we let memory and guessing do the work that might reasonably be demanded of a really complete alphabet.

But, whatever its defects, the existing alphabet is a marvelous piece of mechanism, the result of thousands of years of intellectual effort. It is, perhaps without exception, the most stupendous invention of the human intellect within historical times—an achievement taking rank with such great prehistoric discoveries as the use of articulate speech, the making of a fire, and the invention of stone implements, of the wheel and axle, and of picture-writing. It made possible for the first time that education of the masses upon which all later progress of civilization was so largely to depend

A CRETAN GODDESS

V

A RETROSPECTIVE GLANCE AT CLASSICAL SCIENCE

IT is a favorite tenet of the modern historian that history is a continuous stream. The contention has fullest warrant. Sharp lines of demarcation are an evidence of man's analytical propensity rather than the work of nature. Nevertheless it would be absurd to deny that the stream of history presents an ever-varying current.

There are times when it seems to rush rapidly on; times when it spreads out into a broad—seemingly static—current; times when its catastrophic changes remind us of nothing but a gigantic cataract. Rapids and whirlpools, broad estuaries and tumultuous cataracts are indeed part of the same stream, but they are parts that vary one from another in their salient features in such a way as to force the mind to classify them as things apart and give them individual names.

So it is with the stream of history; however strongly we insist on its continuity we are none the less forced to recognize its periodicity. It may not be desirable to fix on specific dates as turning-points to the extent that our predecessors were wont to do. We may not, for example, be disposed to admit that the Roman Empire came to any such cataclysmic finish as the year 476 A.D., when cited in connection with the overthrow of the last Roman Empire of the West, might seem to indicate. But, on the other hand, no student of the period can fail to

LAKONIAN (GREEK) INSCRIPTION OF
FIFTH CENTURY B C.

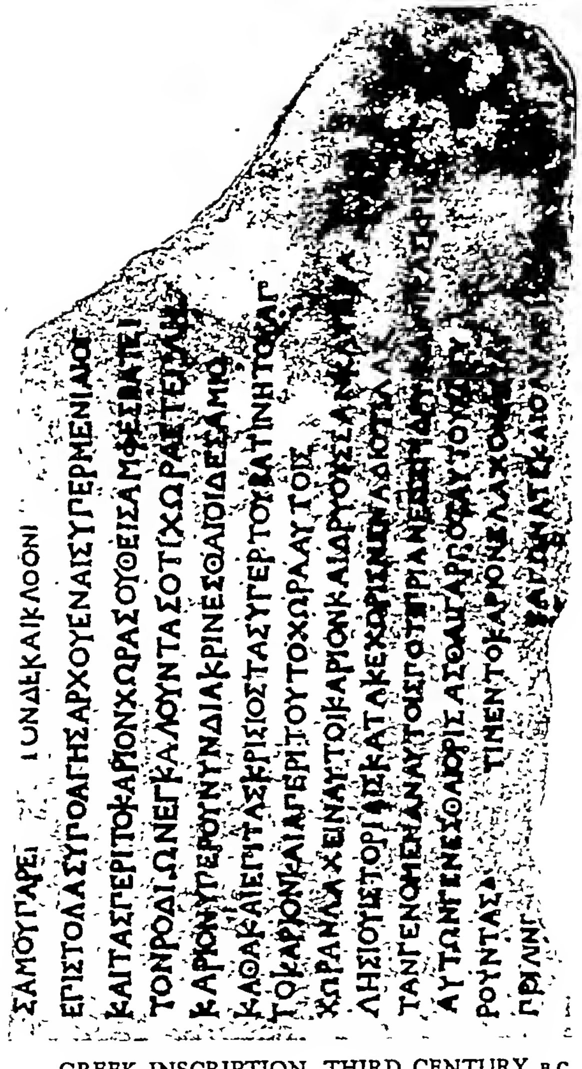
realize that a great change came over the aspect of the historical stream toward the close of the Roman epoch

The span from Thales to Galen has compassed about eight hundred years — let us say thirty generations Throughout this period there is scarcely a generation that has not produced great scientific thinkers — men who have put their mark upon the progress of civilization; but we shall see, as we look forward for a corresponding period, that the ensuing thirty generations produced scarcely a single scientific thinker of the first rank. Eight hundred years of intellectual activity — thirty generations of greatness; then eight hundred years of stasis—thirty generations of mediocrity, such seems to be the record as viewed in perspective

Doubtless it seemed far different to the contemporary observer; it is only in reasonable perspective that any scene can be viewed fairly. But for us, looking back without prejudice across the stage of years, it seems indisputable that a great epoch came to a close at about the time when the barbarian nations of Europe began to sweep down into Greece and Italy. We are forced to feel that we have reached the limits of progress of what historians are pleased to call the ancient world. For about eight hundred years Greek thought has been dominant, but in the ensuing period it is to play a quite subordinate part, except in so far as it influences the thought of an alien race.

As we leave this classical epoch, then, we may well recapitulate in brief its triumphs. A few words will suffice to summarize a story the details of which have made up our recent chapters.

In the field of cosmology, Greek genius has demonstrated that the earth is spheroidal, that the moon is earthlike in structure and much smaller than our globe,



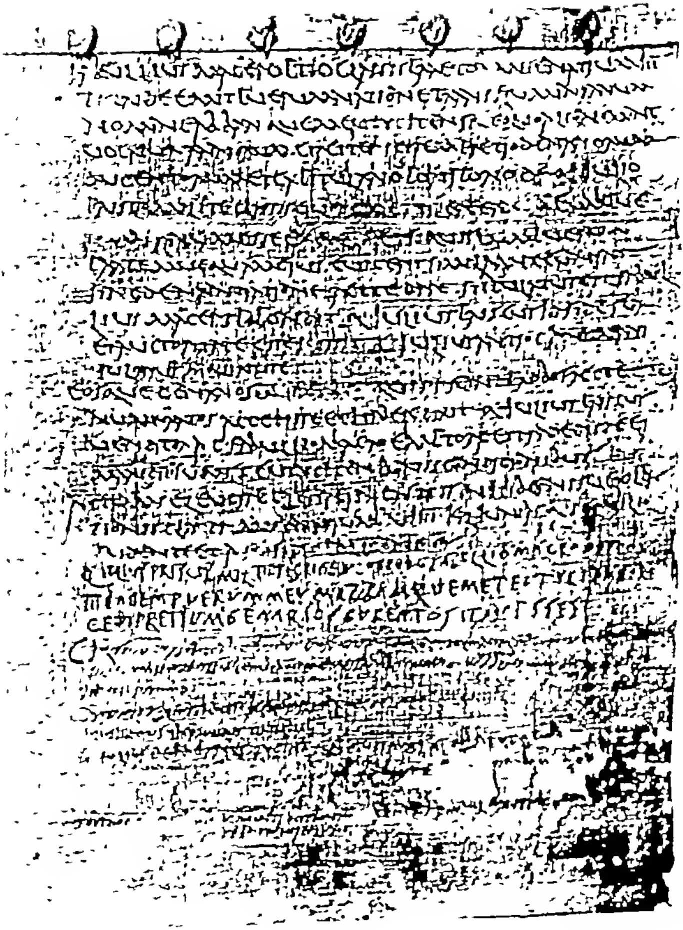
GREEK INSCRIPTION, THIRD CENTURY B C.

and that the sun is vastly larger and many times more distant than the moon. The actual size of the earth and the angle of its axis with the ecliptic have been measured with approximate accuracy It has been shown that the sun and moon present inequalities of motion which may be theoretically explained by supposing that the earth is not situated precisely at the center of their orbits. A system of eccentrics and epicycles has been elaborated which serves to explain the apparent motions of the heavenly bodies in a manner that may be called scientific even tho it is based, as we now know, upon a false hypothesis.

The true hypothesis, which places the sun at the center of the planetary system and postulates the orbital and axial motions of our earth in explanation of the motions of the heavenly bodies, had been put forward and ardently championed, but, unfortunately, was not accepted by the dominant thinkers at the close of the epoch. In this regard, therefore, a vast revolutionary work remained for the thinkers of a later period. Moreover, such observations as the precession of the equinoxes and the moon's evection were as yet unexplained, and measurements of the earth's size, and of the sun's size and distance, were so crude and imperfect as to be in one case only an approximation, and in the other an absurdly inadequate suggestion.

But with all these defects, the total achievement of the Greek astronomers was stupendous. To have clearly grasped the idea that the earth is round is in itself an achievement that marks off the classical from the Oriental period as by a great gulf.

In the physical sciences there had been at least the beginnings of great things. Dynamics and hydrostatics may now, for the first time, claim a place among the



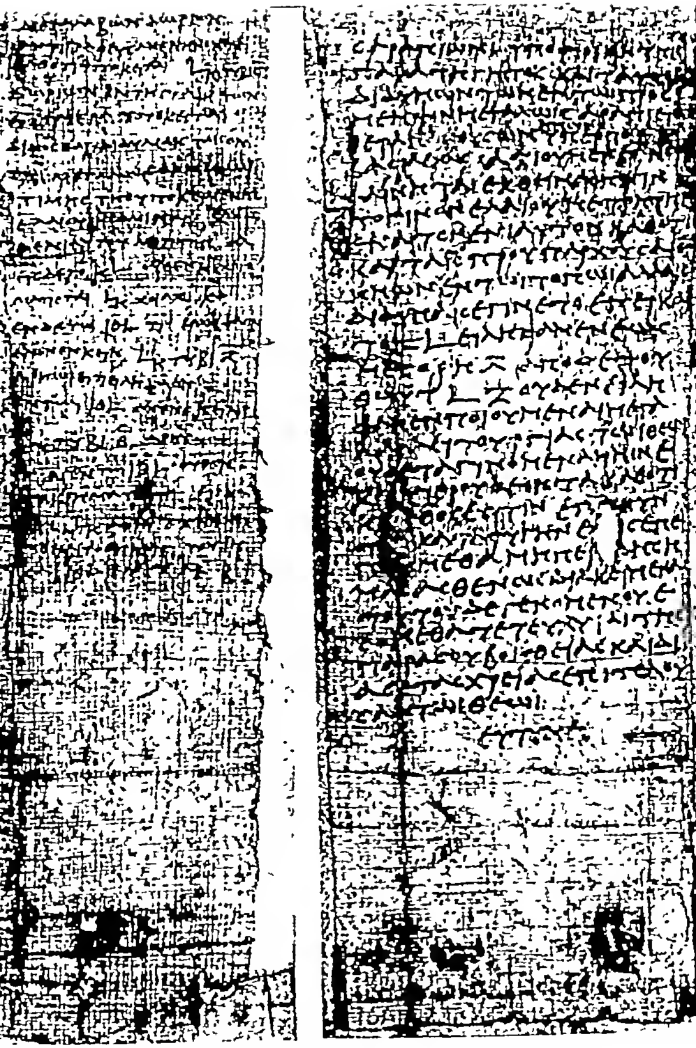
THE SALE OF A SLAVE· GREEK, ON PAPYRUS

sciences Geometry has been perfected and trigonometry has made a sure beginning The conception that there are four elementary substances—earth, water, air, and fire—may not appear a secure foundation for chemistry, yet it marks at least an attempt in the right direction Similarly, the conception that all matter is made up of indivisible particles and that these have adjusted themselves and are perhaps held in place by a whirling motion, *while it is scarcely more than a scientific dream*, is, after all, a dream of marvelous insight

In the field of biological science progress has not been so marked, yet the elaborate garnering of facts regarding anatomy, physiology, and the zoological sciences is at least a valuable preparation for the generalizations of a later time

If with a map before us we glance at the portion of the globe which was known to the workers of the period now in question, bearing in mind at the same time what we have learned as to the seat of labors of the various great scientific thinkers from Thales to Galen, we cannot fail to be struck with a rather startling fact, intimations of which have been given from time to time—the fact, namely, that most of the great Greek thinkers did not live in Greece itself.

As our eye falls upon Asia Minor and its outlying islands, we reflect that here were born such men as Thales, Anaximander, Anaximenes, Heraclitus, Pythagoras, Anaxagoras, Socrates, Aristarchus, Hipparchus, Eudoxus, Philolaus, and Galen. From the northern shores of the Ægean came Lucippus, Democritus, and Aristotle. Italy, off to the west, is the home of Pythagoras and Xenophanes in their later years, and of Parmenides and Empedocles, Zeno, and Archimedes Northern Africa can claim, by birth or by adoption, such names



PETITIONS IN GREEK ON PAPYRUS

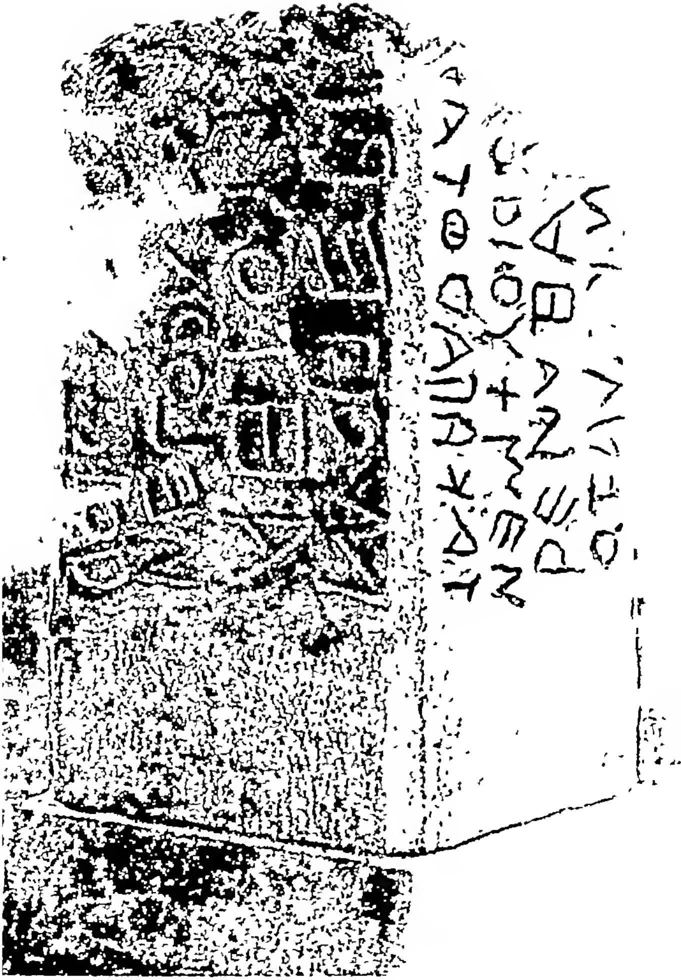
as Euclid, Apollonius of Perga, Herophilus, Erasistratus, Aristippus, Eratosthenes, Ctesibius, Hero, Strabo, and Ptolemy. Were we to extend the list to include a host of workers of the second rank, we should but emphasize the same fact

All along we are speaking of Greeks, or, as they call themselves, Hellenes, and we mean by these words the people whose home was a small jagged peninsula jutting into the Mediterranean at the southeastern extremity of Europe. We think of this peninsula as the home of Greek culture, yet of all the great thinkers we have just named, not one was born on this peninsula, and perhaps not one in five ever set foot upon it.

In point of fact, one Greek thinker of the very first rank, and one only, was born in Greece proper; that one, however, was Plato, perhaps the greatest of them all. With this one brilliant exception (and even he was born of parents who came from the provinces), all the great thinkers of Greece had their origin at the circumference rather than the center of the empire.

And if we reflect that this circumference of the Greek world was in the nature of the case the widely circling region in which the Greek came in contact with other nations, we shall see at once that there could be no more striking illustration in all history than that furnished us here of the value of racial mingling as a stimulus to intellectual progress.

But there is one other feature of the matter that must not be overlooked. Racial mingling gives vitality, but to produce the best effect the mingling must be that of races all of which are at a relatively high plane of civilization. In Asia Minor the Greek mingled with the Semite, who had the heritage of centuries of culture; and in Italy with the Umbrians, Oscans, and Etruscans,



EARLY INSCRIPTION FROM THE ROMAN FORUM

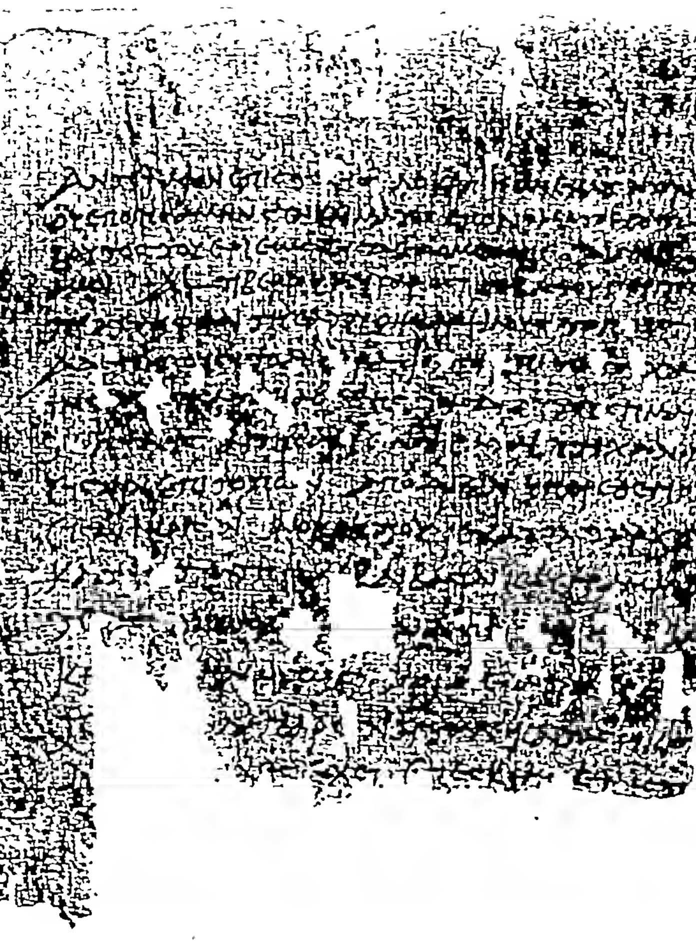
who, little as we know of their antecedents, have left us monuments to testify to their high development.

The chief reason why the racial mingling of a later day did not avail at once to give new life to Roman thought was that the races which swept down from the north were barbarians It was no more possible that they should spring to the heights of classical culture than it would, for example, be possible in two or three generations to produce a racer from a stock of draught horses Evolution does not proceed by such vaults as this would imply Celt, Goth, Hun, and Slav must undergo progressive development for many generations before the population of northern Europe can catch step with the classical Greek and prepare to march forward.

That, perhaps, is one reason why we come to a period of stasis or retrogression when the time of classical activity is over. But, at best, it is only one reason of several

The influence of the barbarian nations will claim further attention as we proceed. But now, for the moment, we must turn our eyes in the other direction and give attention to certain phases of Greek and of Oriental thought which were destined to play a most important part in the development of the Western mind—a more important part, indeed, in the early medieval period than that played by those important inductions of science which have chiefly claimed our attention in recent chapters. The subject in question is the old familiar one of false inductions or pseudo-science.

It must not be inferred that Greek science, with all its secure inductions, was entirely free from superstition On the contrary, the most casual acquaintance with Greek literature would suffice to show the incorrectness of such a supposition. True, the great thinkers of Greece



A GREEK LETTER OF ABOUT THE YEAR 15 A.D

were probably freer from this thraldom of false inductions than any of their predecessors. Even at a very early day such men as Xenophanes, Empedocles, Anaxagoras, and Plato attained to a singularly rationalistic conception of the universe.

"The father of medicine," Hippocrates, banished demonology and conceived disease as due to natural causes. At a slightly later day the sophists challenged all knowledge, and Pyrrhonism became a synonym for skepticism in recognition of the leadership of a master doubter. The entire school of Alexandrians must have been relatively free from superstition, else they could not have reasoned with such effective logicality from their observations of nature

It is almost inconceivable that men like Euclid and Archimedes, and Aristarchus and Eratosthenes, and Hipparchus and Hero, could have been the victims of such illusions regarding occult forces of nature as were constantly postulated by Oriental science. Herophilus and Erasistratus and Galen would hardly have pursued their anatomical studies with equanimity had they believed that ghostly apparitions watched over living and dead alike, and exercised at will a malign influence.

Doubtless the Egyptian of the period considered the work of the Ptolemaic anatomists an unspeakable profanation, and, indeed, it was nothing less than revolutionary—so revolutionary that it could not be sustained in subsequent generations. The great Galen, at Rome, five centuries after the time of Herophilus, was prohibited from dissecting the human subject. The fact speaks volumes for the attitude of the Roman mind toward science.

Vast audiences made up of every stratum of society thronged the amphitheater, and watched exultingly

GREEK INSCRIPTIONS ON FRAGMENTS OF POTTERY

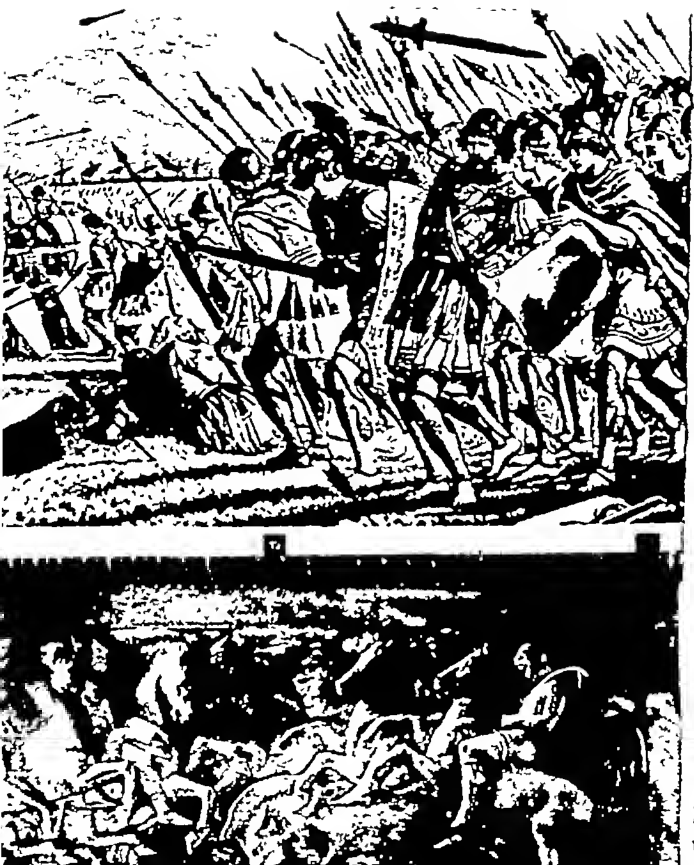
while man slew his fellow-man in single or in multiple combat. Shouts of frenzied joy burst from a hundred thousand throats when the death-stroke was given to a new victim. The bodies of the slain, by scores, even by hundreds, were dragged ruthlessly from the arena and hurled into a ditch as contemptuously as if pity were yet unborn and human life the merest bauble

Yet the same eyes that witnessed these scenes with ecstatic approval would have been averted in pious horror had an anatomist dared to approach one of the mutilated bodies with the scalpel of science It was sport to see the blade of the gladiator enter the quivering, living flesh of his fellow-gladiator; it was joy to see the warm blood spurt forth from the writhing victim while he still lived; but it were sacrilegious to approach that body with the knife of the anatomist, once it had ceased to pulsate with life.

Life itself was held utterly in contempt, but about the realm of death hovered the threatening ghosts of superstition. And such, be it understood, was the attitude of the Roman populace in the early and the most brilliant epoch of the empire, before the Western world came under the influence of that Oriental philosophy which was presently to encompass it.

In this regard the Alexandrian world was, as just intimated, far more advanced than the Roman, yet even there we must suppose that the leaders of thought were widely at variance with the popular conceptions A few illustrations, drawn from Greek literature at various ages, will suggest the popular attitude.

In the first instance, consider the poems of Homer and of Hesiod. For these writers, and doubtless for the vast majority of their readers, not merely of their own but of many subsequent generations, the world is

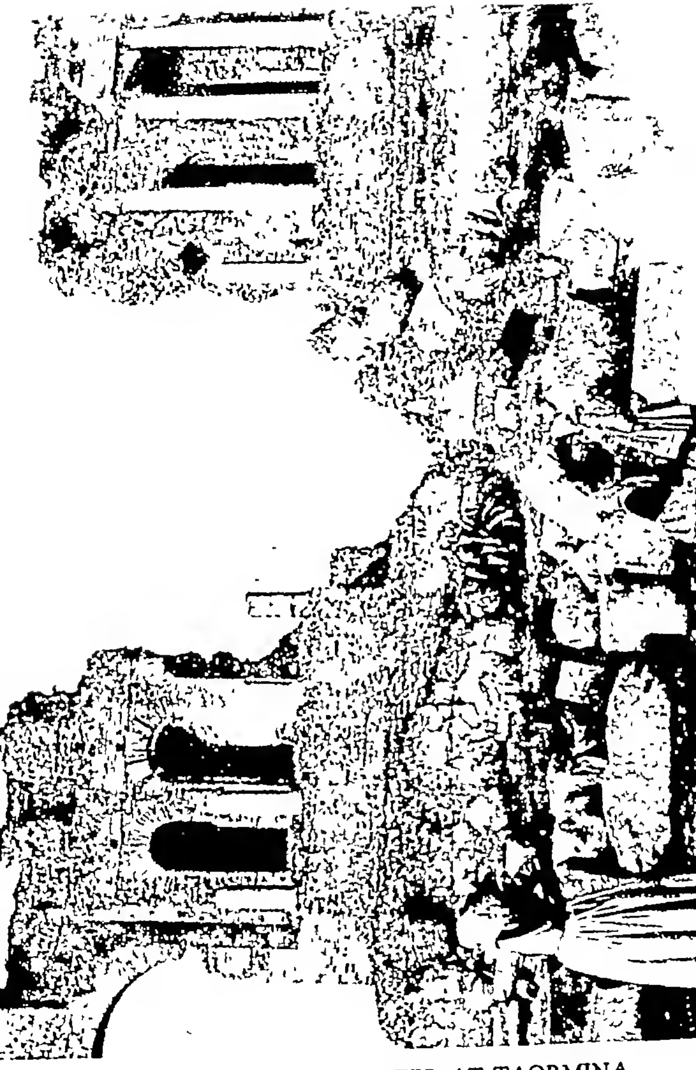


BATTLE OF PERSIANS AND GREEKS —
GREEK SARCOPHAGUS

peopled with a multitude of invisible apparitions, which, under title of gods, are held to dominate the affairs of man. It is sometimes difficult to discriminate as to where the Greek imagination drew the line between fact and allegory; nor need we attempt to analyze the early poetic narratives to this end It will better serve our present purpose to cite three or four instances which illustrate the tangibility of beliefs based upon pseudo-scientific inductions.

Let us cite, for example, the account which Herodotus gives us of the actions of the Greeks at Platæa, when their army confronted the remnant of the army of Xerxes, in the year 479 B.C. Here we see each side hesitating to attack the other, merely because the oracle had declared that whichever side struck the first blow would lose the conflict. Even after the Persian soldiers, who seemingly were a jot less superstitious or a shade more impatient than their opponents, had begun the attack, we are told that the Greeks dared not respond at first, tho they were falling before the javelins of the enemy, because, forsooth, the entrails of a fowl did not present an auspicious appearance. And these were Greeks of the same generation with Empedocles and Anaxagoras and Æschylus; of the same epoch with Pericles and Sophocles and Euripides and Phidias. Such was the scientific status of the average mind—nay, of the best minds, with here and there a rare exception—in the golden age of Grecian culture.

Were we to follow down the pages of Greek history, we should but repeat the same story over and over. We should, for example, see Alexander the Great balked at the banks of the Hyphasis, and forced to turn back because of inauspicious auguries based as before upon the dissection of a fowl. Alexander himself, to be sure,



RUINS OF GREEK THEATER AT TAORMINA

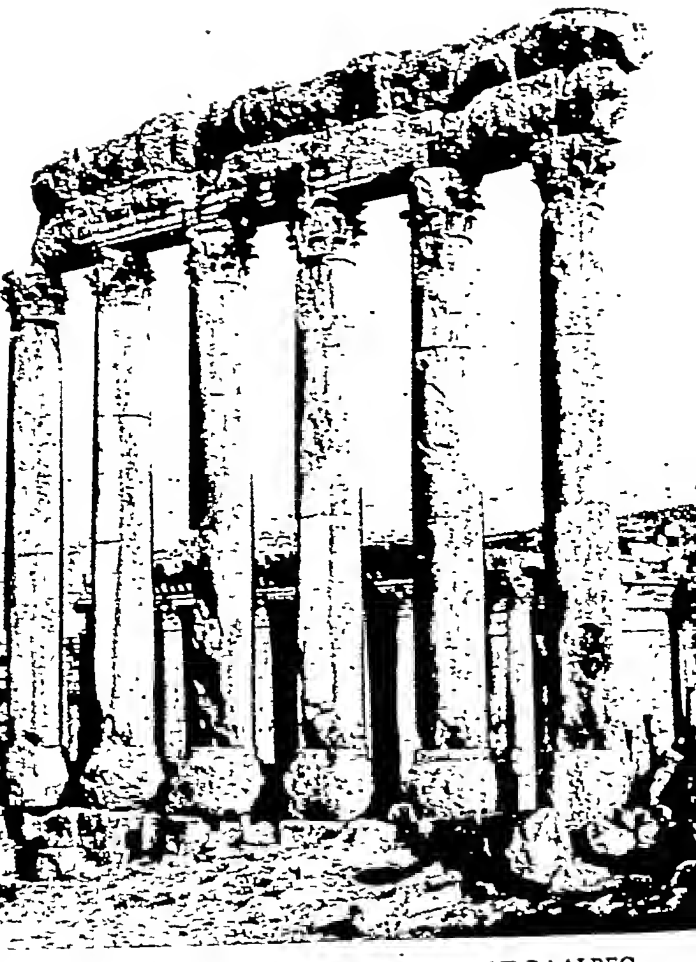
would have scorned the augury; had he been the prey of such petty superstitions he would never have conquered Asia. We know how he compelled the oracle at Delphi to yield to his wishes; how he cut the Gordian knot; how he made his dominating personality felt at the temple of Ammon in Egypt. We know, in a word, that he yielded to superstitions only in so far as they served his purpose Left to his own devices, he would not have consulted an oracle at the banks of the Hyphasis; or, consulting, would have forced from the oracle a favorable answer. But his subordinates were mutinous and he had no choice. Suffice it for our present purpose that the oracle was consulted, and that its answer turned the conqueror back.

One or two instances from Roman history may complete the picture Passing over all those mythical narratives which virtually constitute the early history of Rome, as preserved to us by such historians as Livy and Dionysius, we find so logical an historian as Tacitus recording a miraculous achievement of Vespasian without adverse comment.

"During the months when Vespasian was waiting at Alexandria for the periodical season of the summer winds and a safe navigation, many miracles occurred by which the favor of Heaven and a sort of bias in the powers above toward Vespasian were manifested."

Tacitus then describes in detail the cure of various maladies by the emperor, and relates that the emperor on visiting a temple was met there, in the spirit, by a prominent Egyptian who was proved to be at the same time some eighty miles distant from Alexandria.

It must be admitted that Tacitus, in relating that Vespasian caused the blind to see and the lame to walk, qualifies his narrative by asserting that "persons who



RUINS OF TEMPLE OF THE SUN AT BAALBEC

are present attest the truth of the transaction when there is nothing to be gained by falsehood." Nor must we overlook the fact that a similar belief in the power of royalty has persisted almost to our own day.

But no such savor of skepticism attaches to a narrative which Dion Cassius gives us of an incident in the life of Marcus Aurelius—an incident that has become famous as the episode of The Thundering Legion. Xiphilinus has preserved the account of Dion, adding certain picturesque interpretations of his own

The original narrative, as cited, asserts that during one of the northern campaigns of Marcus Aurelius, the emperor and his army were surrounded by the hostile Quadi, who had every advantage of position and who presently ceased hostilities in the hope that heat and thirst would deliver their adversaries into their hands without the trouble of further fighting.

"Now," says Dion, "while the Romans, unable either to combat or to retreat, and reduced to the last extremity by wounds, fatigue, heat, and thirst, were standing helplessly at their posts, clouds suddenly gathered in great number and rain descended in floods—certainly not without divine intervention, since the Egyptian Maege Arnulphis, who was with Marcus Antoninus, is said to have invoked several genii of the aerial mercury by enchantment, and thus through them had brought down rain."

Here, it will be observed, a supernatural explanation is given of a natural phenomenon. But the narrator does not stop with this. If we are to accept the account of Xiphilinus, Dion brings forward some striking proofs of divine interference. Xiphilinus gives these proofs in the following remarkable paragraph:

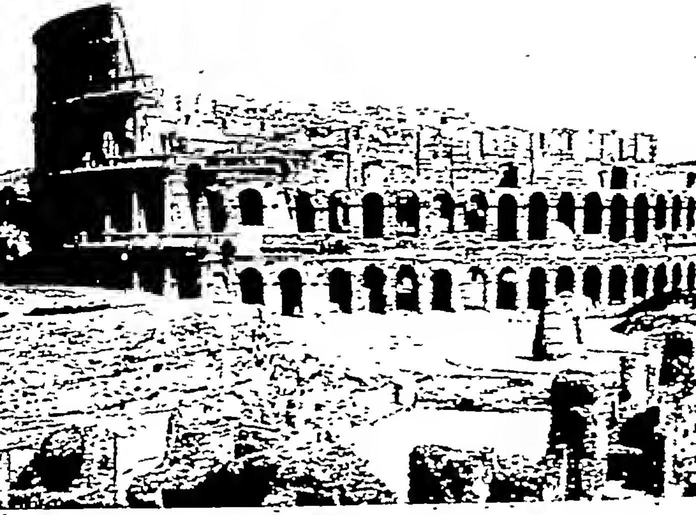
"Dion adds that when the rain began to fall every

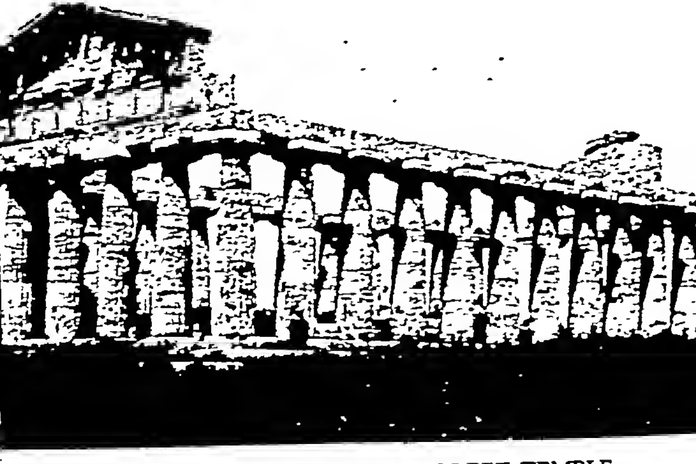
ROMAN ARCH (ARCO FELICE) NEAR NAPLES

soldier lifted his head toward heaven to receive the water in his mouth; but afterwards others held out their shields or their helmets to catch the water for themselves and for their horses Being set upon by the barbarians . . while occupied in drinking, they would have been seriously incommoded had not heavy hail and numerous thunderbolts thrown consternation into the ranks of the enemy Fire and water were seen to mingle as they left the heavens The fire, however, did not reach the Romans, but if it did by chance touch one of them it was immediately extinguished, while at the same time the rain, instead of comforting the barbarians, seemed merely to excite like oil the fire with which they were being consumed. Some barbarians inflicted wounds upon themselves as tho their blood had power to extinguish flames, while many rushed over to the side of the Romans, hoping that there water might save them."

We cannot better complete these illustrations of pagan credulity than by adding the comment of Xiphilinus himself. That writer was a Christian, living some generations later than Dion. He never thought of questioning the facts, but he felt that Dion's interpretation of these facts must not go unchallenged. As he interprets the matter, it was no pagan magician that wrought the miracle. He even inclines to the belief that Dion himself was aware that Christian interference, and not that of an Egyptian, saved the day. "Dion knew," he declares, "that there existed a legion called The Thundering Legion, which name was given it for no other reason than for what came to pass in this war," and that this legion was composed of soldiers from Militene who were all professed Christians.

"During the battle," continues Xiphilinus, "the chief of the Pretorians had sent to Marcus Antoninus, who



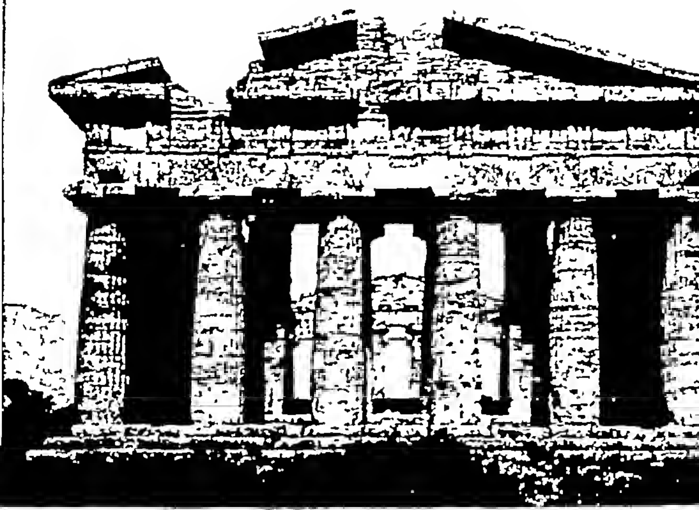


ROMAN COLOSSEUM — GREEK TEMPLE
AT PÆSTUM

was in great perplexity at the turn events were taking, representing to him that there was nothing the people called Christians could not obtain by their prayers, and that among his forces was a troop composed wholly of followers of that religion. Rejoiced at this news, Marcus Antoninus demanded of these soldiers that they should pray to their god, who granted their petition on the instant, sent lightning among the enemy and consoled the Romans with rain. Struck by this wonderful success, the emperor honored the Christians in an edict and named their legion The Thundering. It is even asserted that a letter existed by Marcus Antoninus on this subject. The pagans well knew that the company was called The Thunderers, having attested the fact themselves, but they revealed nothing of the occasion on which the leader received the name."

Peculiar interest attaches to this narrative as illustrating both credulousness as to matters of fact and pseudo-scientific explanation of alleged facts. The modern interpreter may suppose that a violent thunderstorm came up during the course of a battle between the Romans and the so-called barbarians, and that owing to the local character of the storm, or a chance discharge of lightning, the barbarians suffered more than their opponents.

We may well question whether the philosophical emperor himself put any other interpretation than this upon the incident. But, on the other hand, we need not doubt that the major part of his soldiers would very readily accept such an explanation as that given by Dion Cassius, just as most readers of a few centuries later would accept the explanation of Xiphilinus. It is well to bear this thought in mind in considering the static period of science upon which we are entering.



TEMPLES: GREEK (PÆSTUM) AND
ARABIAN (CORDOBA)

We shall perhaps best understand this period, and its seeming retrogressions, if we suppose that the average man of the Middle Ages was no more credulous, no more superstitious, than the average Roman of an earlier period or than the average Greek; tho the precise complexion of his credulity had changed under the influence of Oriental ideas, as we have just seen illustrated by the narrative of Xiphilinus.

EXCAVATION OF POMPEII

CICERO'S ARATEA (A TRANSLATION) OF NINTH OR TENTH CENTURY

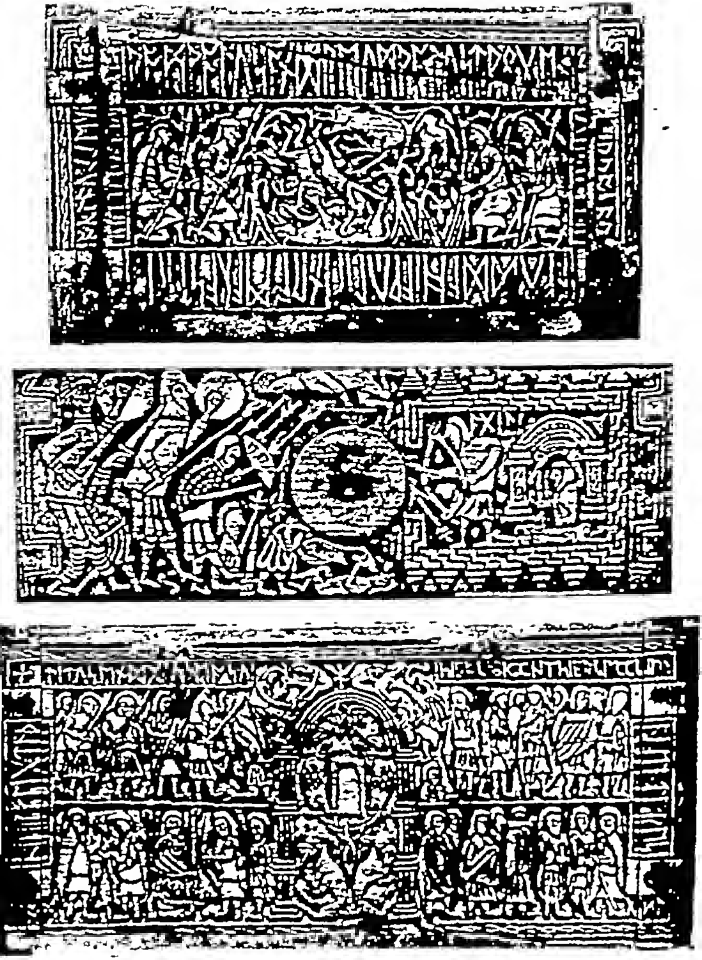
VI

SCIENCE IN THE DARK AGE

AN obvious distinction between the classical and medieval epochs may be found in the fact that the former produced, whereas the latter failed to produce, a few great thinkers in each generation who were imbued with that skepticism which is the foundation of the investigating spirit; who thought for themselves and supplied more or less rational explanations of observed phenomena. Could we eliminate the work of some score or so of classical observers and thinkers, the classical epoch would seem as much a dark age as does the epoch that succeeded it.

But immediately we are met with the question: Why do no great original investigators appear during all these later centuries? A part explanation appears in the fact that the borders of civilization, where racial mingling naturally took place, were peopled with semi-barbarians. But we must not forget that in the centers of civilization all along there were many men of powerful intellect. Indeed, it would violate the principle of historical continuity to suppose that there was any sudden change in the level of mentality of the Roman world at the close of the classical period.

We must assume, then, that the direction in which the great minds turned was for some reason changed. Newton is said to have alleged that he made his discoveries by "intending" his mind in a certain direction continuously. It is probable that the same explanation may



RUNIC INSCRIPTION ON A WHALEBONE CASKET

be given of almost every great scientific discovery. Anaxagoras could not have thought out the theory of the moon's phases; Aristarchus could not have found out the true mechanism of the solar system; Eratosthenes could not have developed his plan for measuring the earth, had not each of these investigators "intended" his mind persistently toward the problems in question.

Nor can we doubt that men lived in every generation of the dark age who were capable of creative thought in the field of science, had they chosen similarly to "intend" their minds in the right direction. The difficulty was that they did not so choose. Their minds had a quite different bent. They were under the spell of different ideals; all their mental efforts were directed into different channels. What these different channels were cannot be in doubt—they were the channels of Oriental ecclesiasticism.

One all-significant fact speaks volumes here. It is the fact that, as Professor Robinson points out, from the time of Boethius (died 524 or 525 A.D.) to that of Dante (1265-1321 A.D.) there was not a single writer of renown in western Europe who was not a professional churchman. All the learning of the time, then, centered in the priesthood. We know that the same condition of things obtained in Egypt when science became static there. But, contrariwise, in Greece and early Rome the scientific workers were largely physicians or professional teachers; there was scarcely a professional theologian among them.

Similarly, in the Arabic world, where alone there was progress in the medieval epoch, the learned men were, for the most part, physicians. Now the meaning of this must be self-evident. The physician naturally "intends" his mind toward the practicalities. His professional stud-

DIOSCORDES: A TREATISE ON PLANTS, SEVENTH CENTURY

ies tend to make him an investigator of the operations of nature. He is usually a skeptic, with a spontaneous interest in practical science.

But the theologian "intends" his mind away from practicalities and toward mysticism. He is a professional believer in the supernatural; he discounts the value of merely "natural" phenomena. His whole attitude of mind is unscientific; the fundamental tenets of his faith are based on alleged occurrences which inductive science cannot admit—namely, miracles. And so the minds "intended" toward the supernatural achieved only the hazy mysticism of medieval thought. Instead of investigating natural laws, they paid heed (as, for example, Thomas Aquinas does in his *Summa Theologia*) to the "acts of angels," the "speaking of angels," the "subordination of angels," the "deeds of guardian angels," and the like.

They disputed such important questions as, How many angels can stand upon the point of a needle? They argued pro and con as to whether Christ were coeval with God, or whether he had been merely created "in the beginning," perhaps ages before the creation of the world.

How could it be expected that science should flourish when the greatest minds of the age could concern themselves with problems such as these?

Despite our preconceptions or prejudices, there can be but one answer to that question. Oriental superstition cast its blight upon the fair field of science, whatever compensation it may or may not have brought in other fields. But we must be on our guard lest we overestimate or incorrectly estimate this influence. Posterity, in glancing backward, is always prone to stamp any given age of the past with one idea, and to desire to characterize it with a single phrase; whereas in reality

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TERRA EPI BAIOCENSIS

DOMESDAY BOOK (A.D. 1086)

all ages are diversified, and any generalization regarding an epoch is sure to do that epoch something less or something more than justice.

We may be sure, then, that the ideal of ecclesiasticism is not solely responsible for the scientific stasis of the dark age. Indeed, there was another influence of a totally different character that is too patent to be overlooked—the influence, namely, of the economic condition of western Europe during this period.

Italy, the center of western civilization, was at this time impoverished, and hence could not provide the monetary stimulus so essential to artistic and scientific no less than to material progress. There were no patrons of science and literature such as the Ptolemies of that elder Alexandrian day. There were no great libraries; no colleges to supply opportunities and afford stimuli to the rising generation. Worst of all, it became increasingly difficult to secure books.

This phase of the subject is often overlooked. Yet a moment's consideration will show its importance. How should we fare today if no new scientific books were being produced, and if the records of former generations were destroyed? That is what actually happened in Europe during the Middle Ages.

At an earlier day books were made and distributed much more abundantly than is sometimes supposed. Bookmaking had, indeed, been an important profession in Rome, the actual makers of books being slaves who worked under the direction of a publisher. It was through the efforts of these workers that the classical works in Greek and Latin were multiplied and disseminated.

Unfortunately the climate of Europe does not conduce to the indefinite preservation of a book; hence very few remnants of classical works have come down to us

in the original from a remote period. The rare exceptions are certain papyrus fragments, found in Egypt, some of which are Greek manuscripts dating from the third century B.C.

Even from these sources the output is meager; and the only other repository of classical books is a single room in the buried city of Herculaneum, which contained several hundred manuscripts, mostly in a charred condition, a considerable number of which, however, have been unrolled and found more or less legible. This library in the buried city was chiefly made up of philosophical works, some of which were quite unknown to the modern world until discovered there.

But this find, interesting as it was from an archeological standpoint, had no very important bearing on our knowledge of the literature of antiquity. Our chief dependence for our knowledge of that literature must still be placed in such copies of books as were made in the successive generations. Comparatively few of the extant manuscripts are older than the tenth century of our era. It requires but a momentary consideration of the conditions under which ancient books were produced to realize how slow and difficult the process was before the invention of printing.

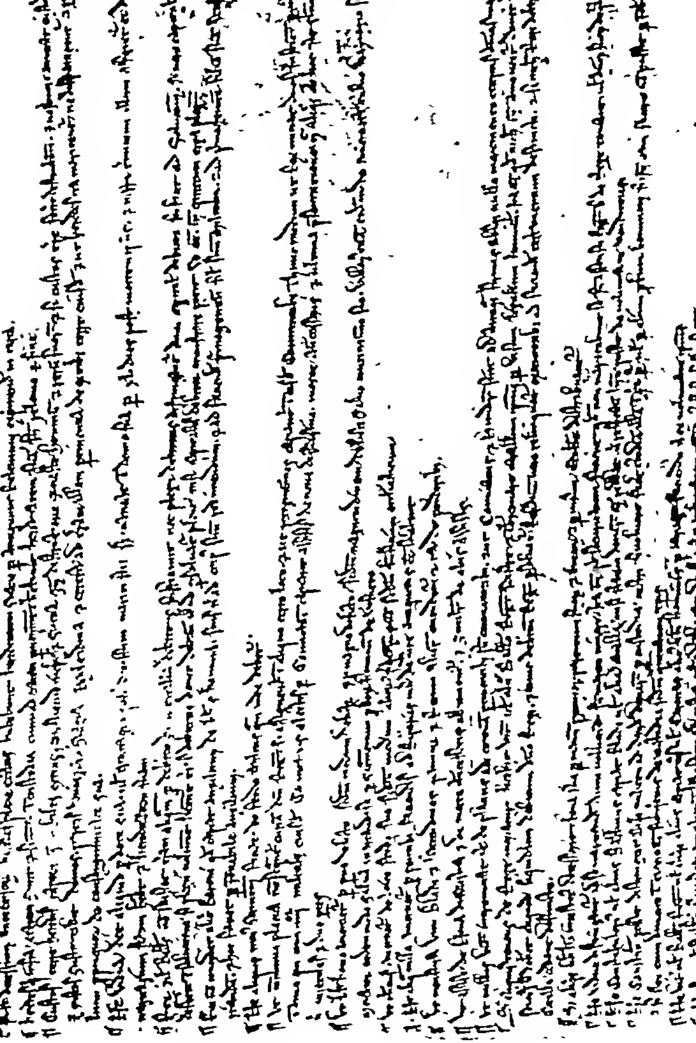
The taste of the book-buying public demanded a clearly written text, and in the Middle Ages it became customary to produce a richly ornamented text as well. The script employed being the prototype of the modern printed text, it will be obvious that a scribe could produce but a few pages at best in a day. A large work would therefore require the labor of a scribe for many months or even for several years. We may assume, then, that it would be a very flourishing publisher who could produce a hundred volumes all told per annum; and

probably there were not many publishers at any given time, even in the period of Rome's greatest glory, who had anything like this output.

As there was a large number of authors in every generation of the classical period, it follows that most of these authors must have been obliged to content themselves with editions numbering very few copies; and it goes without saying that the greater number of books were never reproduced in what might be called a second edition. Even books that retained their popularity for several generations would presently fail to arouse sufficient interest to be copied; and in due course such works would pass out of existence altogether. Doubtless many hundreds of books were thus lost before the close of the classical period, the names of their authors being quite forgotten, or preserved only through a chance reference: and of course the work of elimination went on much more rapidly during the Middle Ages, when the interest in classical literature sank to so low an ebb in the West.

Such collections of references and quotations as the Greek Anthology and the famous anthologies of Stobæus and Athanasius and Eusebius give us glimpses of a host of writers—more than seven hundred are quoted by Stobæus—a very large proportion of whom are quite unknown except through these brief excerpts from their lost works

Quite naturally the scientific works suffered at least as largely as any others in an age given over to ecclesiastical dreamings. Yet in some regards there is matter for surprize as to the works preserved. Thus, as we have seen, the very extensive works of Aristotle on natural history, and the equally extensive natural history of Pliny, which were preserved throughout this period and are still extant, make up relatively bulky volumes. These



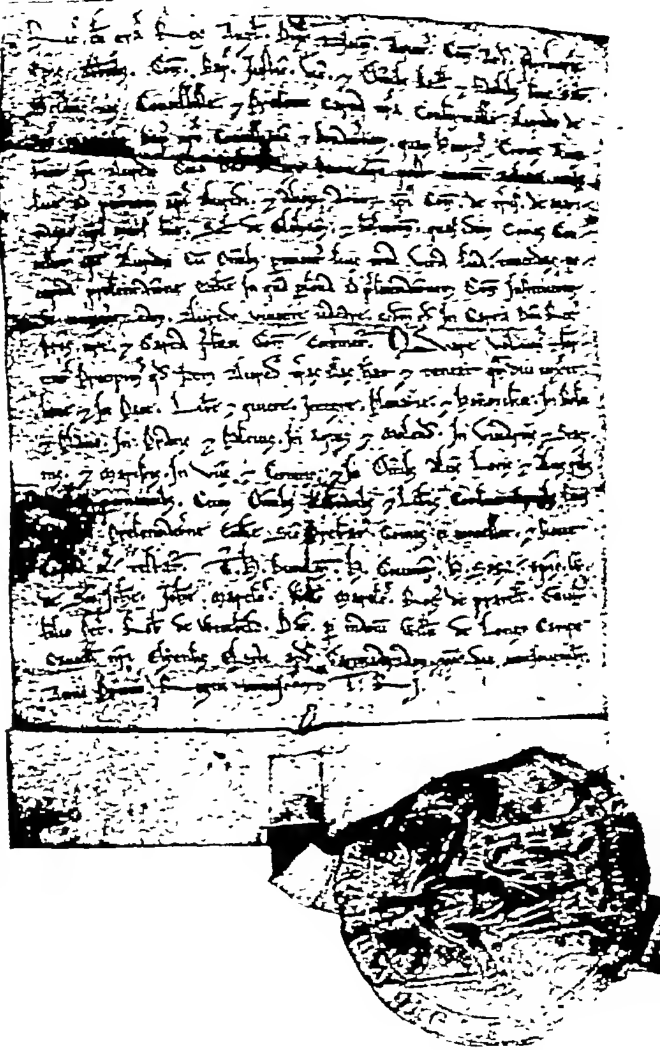
ARTICLES OF MAGNA CARTA

works seem to have interested the monks of the Middle Ages, while many much more important scientific books were allowed to perish. A considerable bulk of scientific literature was also preserved through the curious channels of Arabic and Armenian translations Thus we have the *Almagest* of Ptolemy, which was translated into Arabic, and at a later day brought by the Arabs into western Europe and (at the instance of Frederick II of Sicily) translated out of their language into medieval Latin.

It remains to inquire, however, through what channels the Greek works reached the Arabs themselves. To gain an answer to this question we must follow the stream of history from its Roman course eastward to the new seat of the Roman empire in Byzantium. Here civilization centered from about the fifth century A.D., and here the European came in contact with the civilization of the Syrians, the Persians, the Armenians, and finally of the Arabs. The Byzantines themselves, unlike the inhabitants of western Europe, did not ignore the literature of old Greece; the Greek language became the regular speech of the Byzantine people, and their writers made a strenuous effort to perpetuate the idiom and style of the classical period.

Naturally they also made transcriptions of the classical authors, and thus a great mass of literature was preserved, while the corresponding works were quite forgotten in western Europe.

Meantime many of these works were translated into Syriac, Armenian, and Persian, and when later the Byzantine civilization degenerated, many works that were no longer to be had in the Greek originals continued to be widely circulated in Syriac, Persian, Armenian, and, ultimately, in Arabic translations When the



A CHARTER BY KING RICHARD I, WITH HIS SEAL

Arabs started out in their conquests, which carried them through Egypt and along the southern coast of the Mediterranean until they finally invaded Europe from the west by way of Gibraltar, they carried with them their translation of many a Greek classical author, who was introduced anew to the western world through this strange channel.

We are told, for example, that Averrhoës, the famous commentator of Aristotle, who lived in Spain in the twelfth century, did not know a word of Greek and was obliged to gain his knowledge of the master through a Syriac translation; or, as others alleged (denying that he knew even Syriac), through an Arabic version translated from the Syriac. We know, too, that the famous chronology of Eusebius was preserved through an Armenian translation; and reference has been made to the Arabic translation of Ptolemy's great work, to which we still apply its Arabic title of *Almagest*.

The familiar story that when the Arabs invaded Egypt they burned the Alexandrian library is now regarded as an invention of later times. It seems much more probable that the library had been largely scattered before the coming of the Moslems. Indeed, it has even been suggested that the Christians of an earlier day removed the records of pagan thought. Be that as it may, the famous Alexandrian library had disappeared long before the revival of interest in classical learning.

Meanwhile, as we have said, the Arabs, far from destroying the western literature, were its chief preservers. Partly at least because of their regard for the records of the creative work of earlier generations of alien peoples, the Arabs were enabled to outstrip their contemporaries. For it cannot be in doubt that, during that long stretch of time when the western world was ignor-

RICHARD I AND SALADIN — A WORLD HISTORY OF 1314-15 A.D.

ing science altogether or at most contenting itself with the casual reading of Aristotle and Pliny, the Arabs had the unique distinction of attempting original investigations in science. To them were due all important progressive steps which were made in any scientific field whatever for about a thousand years after the time of Ptolemy and Galen. The progress made even by the Arabs during this long period seems meager enough, yet it has some significant features These will now demand our attention.

INSCRIBED LION FROM NINEVEH

ARABIAN BIOGRAPHY OF MOHAMMED

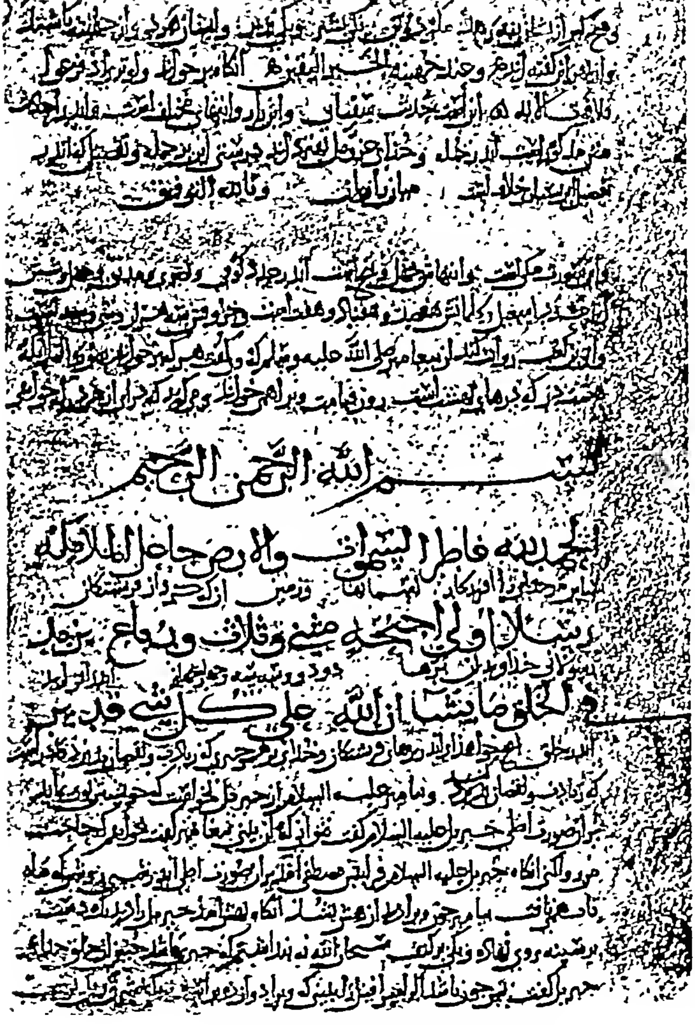
VII

MEDIEVAL SCIENCE AMONG THE ARABIANS

THE successors of Mohammed showed themselves curiously receptive of the ideas of the western people whom they conquered. They came in contact with the Greeks in western Asia and in Egypt, and, as has been said, became their virtual successors in carrying forward the torch of learning.

It must not be inferred, however, that the Arabian scholars, as a class, were comparable to their predecessors in creative genius. On the contrary, they retained much of the conservative Oriental spirit. They were under the spell of tradition, and, in the main, what they accepted from the Greeks they regarded as almost final in its teaching. There were, however, a few notable exceptions among their men of science, and to these must be ascribed several discoveries of some importance.

The chief subjects that excited the interest and exercised the ingenuity of the Arabian scholars were astronomy, mathematics, and medicine. The practical phases of all these subjects were given particular attention. Thus it is well known that our so-called Arabian numerals date from this period. The revolutionary effect of these characters, as applied to practical mathematics, can hardly be overestimated; but it is generally considered, and in fact was admitted by the Arabs themselves, that these numerals were really borrowed from the Hindus, with whom the Arabs came in contact on the east.



بسم الله الرحمن الرحيم

الحمد لله فاطر السموات والارض جاعل الملائكة

رسلا اولي اجنحة مثنى وثلاث ورباع يزيد

في الخلق ما يشاء ان الله على كل شيء قدير

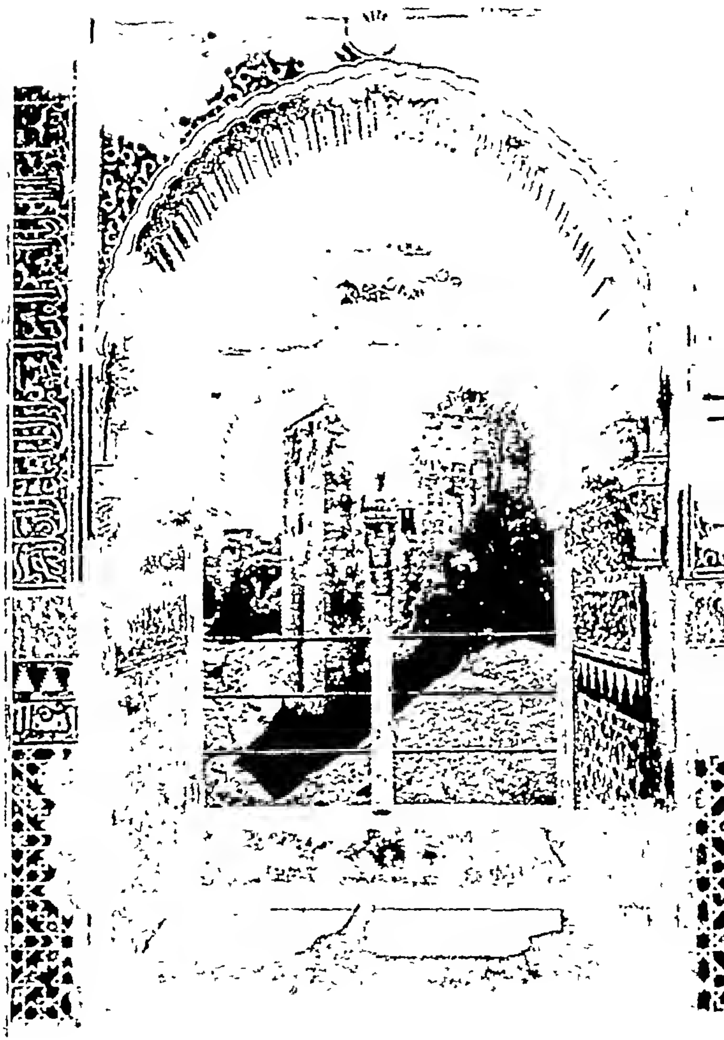
THE KORAN IN ARABIC WITH
INTERLINEATIONS IN PERSIAN

Certain of the Hindu alphabets, notably that of the Battaks of Sumatra, give us clues to the originals of the numerals. It does not seem certain, however, that the Hindus employed these characters according to the decimal system, which is the prime element of their importance. Knowledge is not forthcoming as to just when or by whom such application was made. If this was an Arabic innovation, it was perhaps the most important one with which that nation is to be credited.

Another mathematical improvement was the introduction into trigonometry of the sine—the half-chord of the double arc—instead of the chord of the arc itself which the Greek astronomers had employed This improvement was due to the famous Albategnius, whose work in other fields we shall examine in a moment.

Another evidence of practicality was shown in the Arabian method of attempting to advance upon Eratosthenes' measurement of the earth Instead of trusting to the measurement of angles, the Arabs decided to measure directly a degree of the earth's surface—or rather two degrees. Selecting a level plain in Mesopotamia for the experiment, one party of the surveyors progressed northward, another party southward, from a given point to the distance of one degree of arc, as determined by astronomical observations. The result found was fifty-six miles for the northern degree, and fifty-six and two-thirds miles for the southern Unfortunately, we do not know the precise length of the mile in question, and therefore cannot be assured as to the accuracy of the measurement.

It is interesting to note, however, that the two degrees were found of unequal lengths, suggesting that the earth is not a perfect sphere—a suggestion the validity of which was not to be put to the test of conclusive meas-



MOORISH ARCHES IN THE ALHAMBRA, SPAIN

urements until about the close of the eighteenth century

The Arab measurement was made in the time of Caliph Abdallah al-Mamun, the son of the famous Harun-al-Rashid Both father and son were famous for their interest in science Harun-al-Rashid was, it will be recalled, the friend of Charlemagne It is said that he sent that ruler, as a token of friendship, a marvelous clock which let fall a metal ball to mark the hours This mechanism, which is alleged to have excited great wonder in the West, furnishes yet another instance of Arabian practicality.

Perhaps the greatest of the Arabian astronomers was Mohammed ben Jabir Albategnius, or El-batani, who was born at Batan, in Mesopotamia, about the year 850 A.D., and died in 929. Albategnius was a student of the Ptolemaic astronomy, but he was also a practical observer.

He made the important discovery of the motion of the solar apogee. That is to say, he found that the position of the sun among the stars, at the time of its greatest distance from the earth, was not what it had been in the time of Ptolemy. The Greek astronomer placed the sun in longitude 65°, but Albategnius found it in longitude 82°, a distance too great to be accounted for by inaccuracy of measurement The modern inference from this observation is that the solar system is moving through space; but of course this inference could not well be drawn while the earth was regarded as the fixed center of the universe.

In the eleventh century another Arabian discoverer, Arzachel, observing the sun to be less advanced than Albategnius had found it, inferred incorrectly that the sun had receded in the meantime. The modern explanation of this observation is that the measurement of Al-

bategnius was somewhat in error, since we know that the sun's motion is steadily progressive. Arzachel, however, accepting the measurement of his predecessor, inferred an oscillatory motion of the stars, the idea of the motion of the solar system not being permissible.

This assumed phenomenon, which really has no existence in point of fact, was named the "trepidation of the fixed stars," and was for centuries accepted as an actual phenomenon. Arzachel explained this supposed phenomenon by assuming that the equinoctial points, or the points of intersection of the equator and the ecliptic, revolve in circles of eight degrees' radius. The first points of Aries and Libra were supposed to describe the circumference of these circles in about eight hundred years. All of which illustrates how a difficult and false explanation may take the place of a simple and correct one. The observations of later generations have shown conclusively that the sun's shift of position is regularly progressive, hence that there is no "trepidation" of the stars and no revolution of the equinoctial points

If the Arabs were wrong as regards this supposed motion of the fixed stars, they made at least one correct observation as to the inequality of motion of the moon. Two inequalities of the motion of this body were already known. A third, called the moon's variation, was discovered by an Arabian astronomer who lived at Cairo and observed at Bagdad in 975, and who bore the formidable name of Mohammed Aboul Wefaal-Bouzdjani. The inequality of motion in question, in virtue of which the moon moves quickest when she is at new or full, and slowest at the first and third quarter, was rediscovered by Tycho Brahe six centuries later; a fact which in itself evidences the neglect of the Arabian astronomer's discovery by his immediate successors.

In the ninth and tenth centuries the Arabian city of Cordoba, in Spain, was another important center of scientific influence There was a library of several hundred thousand volumes here, and a college where mathematics and astronomy were taught Granada, Toledo, and Salamanca were also important centers, to which students flocked from western Europe.

It was the proximity of these Arabian centers that stimulated the scientific interests of Alfonso X of Castile, at whose instance the celebrated Alfonsine tables were constructed A familiar story records that Alfonso, pondering the complications of the Ptolemaic cycles and epicycles, was led to remark that, had he been consulted at the time of creation, he could have suggested a much better and simpler plan for the universe Some centuries were to elapse before Copernicus was to show that it was not the plan of the universe, but man's interpretation of it, that was at fault.

Another royal personage who came under Arabian influence was Frederick II. of Sicily—the "Wonder of the World," as he was called by his contemporaries. The *Almagest* of Ptolemy was translated into Latin at his instance, being introduced to the Western world through this curious channel At this time it became quite usual for the Italian and Spanish scholars to understand Arabic altho they were totally ignorant of Greek.

In the field of physical science one of the most important of the Arabian scientists was Alhazen. His work, published about the year 1100 A.D., had great celebrity throughout the medieval period The original investigations of Alhazen had to do largely with optics. He made particular studies of the eye itself, and the names given by him to various parts of the eye, as the vitreous humor, the cornea, and the retina, are still retained.

EXTRAORDINARY DECORATIONS IN THE ALHAMBRA

Ptolemy had studied the refraction of light, and he, in common with his immediate predecessors, was aware that atmospheric refraction affects the apparent position of stars near the horizon. Alhazen carried forward these studies, and was led through them to make the first recorded scientific estimate of the phenomena of twilight and of the height of the atmosphere.

The persistence of a glow in the atmosphere after the sun has disappeared beneath the horizon is so familiar a phenomenon that the ancient philosophers seem not to have thought of it as requiring an explanation. Yet a moment's consideration makes it clear that, if light travels in straight lines and the rays of the sun were in no wise deflected, the complete darkness of night should instantly succeed to day when the sun passes below the horizon. That this sudden change does not occur, Alhazen explained as due to the reflection of light by the earth's atmosphere.

Alhazen appears to have conceived the atmosphere as a sharply defined layer, and, assuming that twilight continues only so long as rays of the sun reflected from the outer surface of this layer can reach the spectator at any given point, he hit upon a means of measurement that seemed to solve the hitherto inscrutable problem as to the atmospheric depth. Like the measurements of Aristarchus and Eratosthenes, this calculation of Alhazen is simple enough in theory. Its defect consists largely in the difficulty of fixing its terms with precision, combined with the further fact that the rays of the sun, in taking the slanting course through the earth's atmosphere, are really deflected from a straight line by virtue of the constantly increasing density of the air near the earth's surface. Alhazen must have been aware of this latter fact, since it was known to the later Alexandrian

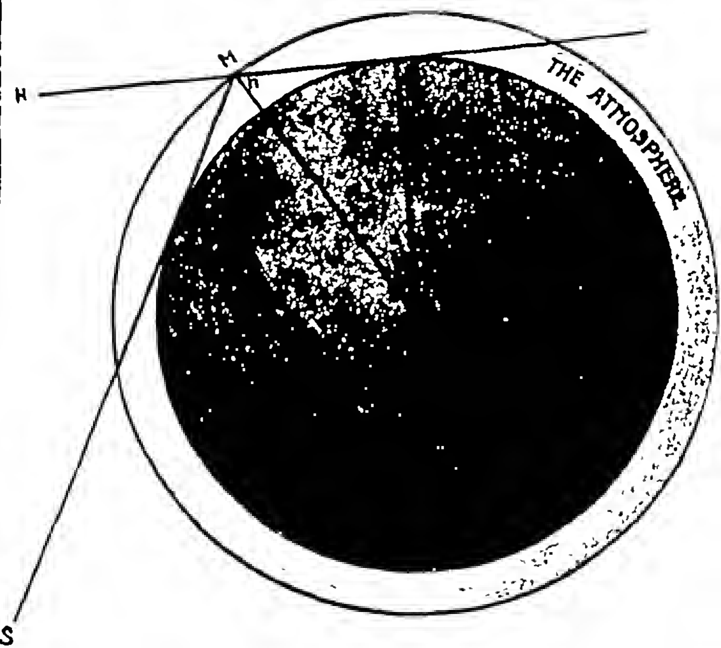


DIAGRAM TO ILLUSTRATE ALHAZEN'S MEASUREMENT OF THE HEIGHT OF THE ATMOSPHERE

astronomers, but he takes no account of it in the present measurement. The diagram will make the method of Alhazen clear.

His important premises are two: first, the well-recognized fact that, when light is reflected from any surface, the angle of incidence is equal to the angle of reflection. and, second, the much more doubtful observation that twilight continues until such time as the sun, according to a simple calculation, is nineteen degrees below the horizon.

Referring to the diagram, let the inner circle represent the earth's surface, the outer circle the limits of the atmosphere, C being the earth's center, and *RR* radii of of the earth. Then the observer at the point A will continue to receive the reflected rays of the sun until that body reaches the point *S*, which is according to the hypothesis, nineteen degrees below the horizon line of the observer at *A*. This horizon line, being represented by *AH*, and the sun's ray by *SM*, the angle *HMS* is an angle of nineteen degrees. The complementary angle *SMA* is, obviously, an angle of (180–19) one hundred and sixty-one degrees. But since *M* is the reflecting surface and the angle of incidence equals the angle of reflection, the angle *AMC* is an angle of one-half of one hundred and sixty-one degrees, or eighty degrees and thirty minutes. Now, this angle *AMC* being known, the right-angled triangle *MAC* is easily resolved, since the side *AC* of that triangle, being the radius of the earth, is a known dimension. Resolution of this triangle gives us the length of the hypotenuse *MC*, and the difference between this and the radius (*AC*), or *CD*, is obviously the height of the atmosphere (*h*), which was the measurement desired.

According to the calculation of Alhazen, this *h*, or

the height of the atmosphere, represents from twenty to thirty miles. The modern computation extends this to about fifty miles. But, considering the various ambiguities that necessarily attended the experiment, the result was a remarkably close approximation to the truth.

Turning from physics to chemistry, we find as perhaps the greatest Arabian name that of Geber, who taught in the College of Seville in the first half of the eighth century. The most important researches of this really remarkable experimenter had to do with the acids. The ancient world had had no knowledge of any acid more powerful than acetic. Geber, however, vastly increased the possibilities of chemical experiment by the discovery of sulfuric, nitric, and nitromuriatic acids. He made use also of the processes of sublimation and filtration, and his works describe the water bath and the chemical oven. Among the important chemicals which he first differentiated is oxid of mercury, and his studies of sulfur in its various compounds have peculiar interest. In particular is this true of his observation that, under certain conditions of oxidation, the weight of a metal was lessened.

From the record of these studies in the fields of astronomy, physics, and chemistry, we turn to a somewhat extended survey of the Arabian advances in the field of medicine.

The influence of Arabian physicians rested chiefly upon their use of drugs rather than upon anatomical knowledge. Like the medieval Christians, they looked with horror on dissection of the human body; yet there were always among them investigators who turned constantly to nature herself for hidden truths, and were ready to uphold the superiority of actual observation to mere reading.

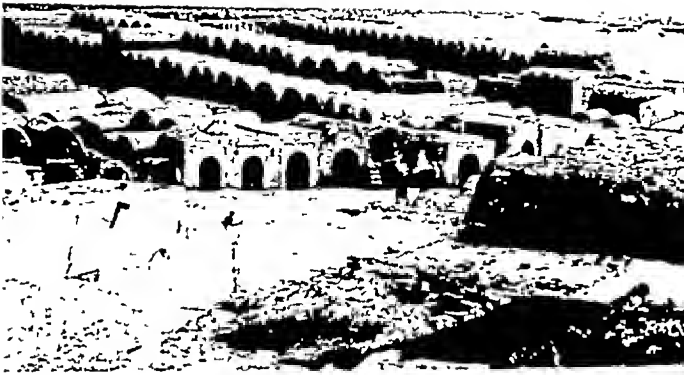
Thus the physician Abd el-Letif, while in Egypt, made

careful studies of a mound of bones containing more than twenty thousand skeletons While examining these bones he discovered that the lower jaw consists of a single bone, not of two, as had been taught by Galen. He also discovered several other important mistakes in Galenic anatomy, and was so impressed with his discoveries that he contemplated writing a work on anatomy which should correct the great classical authority's mistakes.

It was the Arabs who invented the apothecary, and their pharmacopœia, issued from the hospital at Gondisapor, and elaborated from time to time, formed the basis for Western pharmacopœias. Just how many drugs originated with them, and how many were borrowed from the Hindus, Jews, Syrians, and Persians, cannot be determined. It is certain, however, that through them various new and useful drugs, such as senna, aconite, rhubarb, camphor and mercury, were handed down through the Middle Ages, and that they are responsible for the introduction of alchohol in the field of therapeutics.

In medieval Europe, Arabian science came to be regarded with superstitious awe, and the works of certain Arabian physicians were exalted to a position above all the ancient writers. In modern times, however, there has been a reaction and a tendency to depreciation of their work. By some they are held to be mere copyists or translators of Greek books, and in no sense original investigators in medicine. Yet there can be little doubt that while the Arabians did copy and translate freely, they also originated and added considerably to medical knowledge.

It is certain that in the time when Christian monarchs in western Europe were paying little attention to science



VILLAGE OF THE "CLIMBING TROGLODYTES," TUNISIA — DAMASCUS

or education, the caliphs and vizirs were encouraging physicians and philosophers, building schools, and erecting libraries and hospitals They made at least a creditable effort to uphold and advance upon the scientific standards of an earlier age.

The first distinguished Arabian physician was Harets ben Kaladah, who received his education in the Nestonian school at Gondisapor, about the beginning of the seventh century. Notwithstanding the fact that Harets was a Christian, he was chosen by Mohammed as his chief medical adviser, and recommended as such to his successor, the Caliph Abu Bekr. Thus, at the very outset, the science of medicine was divorced from religion among the Arabians; for if the prophet himself could employ the services of an unbeliever, surely others might follow his example. And that this example was followed is shown in the fact that many Christian physicians were raised to honorable positions by succeeding generations of Arabian monarchs.

This broad-minded view of medicine taken by the Arabs undoubtedly assisted as much as any one single factor in upbuilding the science, just as the narrow and superstitious view taken by Western nations helped to destroy it.

The education of the Arabians made it natural for them to associate medicine with the natural sciences, rather than with religion. An Arabian savant was supposed to be equally well educated in philosophy, jurisprudence, theology, mathematics, and medicine, and to practise law, theology and medicine with equal skill upon occasion. It is easy to understand, therefore, why these religious fanatics were willing to employ unbelieving physicians, and their physicians themselves to turn to the scientific works of Hippocrates and Galen for

medical instruction, rather than to religious works. Even Mohammed himself professed some knowledge of medicine, and often relied upon this knowledge in treating ailments rather than upon prayers or incantations He is said, for example, to have recommended and applied cautery in the case of a friend who, when suffering from angina, had sought his aid.

The list of eminent Arabian physicians is too long to be given here, but some of them are of such importance in their influence upon later medicine that they cannot be entirely ignored One of the first of these was Honain ben Isaac (809-873 A.D.), a Christian Arab of Bagdad. He made translations of the works of Hippocrates, and practised the art along the lines indicated by his teachings and those of Galen. He is considered the greatest translator of the ninth century and one of the greatest philosophers of that period.

Another great Arabian physician, whose work was just beginning as Honain's was drawing to a close, was Rhazes (850-923 A.D.), who during his life was no less noted as a philosopher and musician than as a physician. He continued the work of Honain, and advanced therapeutics by introducing more extensive use of chemical remedies, such as mercurial ointments, sulfuric acid and aqua vitæ. He is also credited with being the first physician to describe small-pox and measles accurately.

Whiles Rhazes was still alive another Arabian, Haly Abbas (died about 994), was writing his famous encyclopedia of medicine, called *The Royal Book*. But the names of all these great physicians have been considerably obscured by the reputation of Avicenna (980-1037), the Arabian "Prince of Physicians," the greatest name in Arabic medicine, and one of the most remarkable men in history. Leclerc says that "he was perhaps

never surpassed by any man in brilliancy of intellect and indefatigable activity." His career was a most varied one. He was at all times a boisterous reveler, but whether flaunting gaily among the guests of an emir or hiding in some obscure apothecary cellar, his work of philosophical writing was carried on steadily When a friendly emir was in power, he taught and wrote and caroused at court; but between times, when some unfriendly ruler was supreme, he was hiding away obscurely, still pouring out his great mass of manuscripts In this way his entire life was spent

By his extensive writings he revived and kept alive the best of the teachings of the Greek physicians, adding to them such observations as he had made in anatomy, physiology, and materia medica. Among his discoveries is that of the contagiousness of pulmonary tuberculosis. His works for several centuries continued to be looked upon as the highest standard by physicians, and he should undoubtedly be credited with having at least retarded the decline of medieval medicine.

But it was not the Eastern Arabs alone who were active in the field of medicine. Cordoba, the capital of the western caliphate, became also a great center of learning and produced several great physicians. One of these, Albucasis (died in 1013 A.D.), is credited with having published the first illustrated work on surgery, this book being remarkable in still another way, in that it was also the first book, since classical times, written from the practical experience of the physician, and not a mere compilation of ancient authors.

A century after Albucasis came the great physician Avenzoar (1113-1196), with whom he divides about equally the medical honors of the western caliphate. Among Avenzoar's discoveries was that of the cause of

A PRAYER NICHE IN THE MOORISH TEMPLE AT CORDOBA

"itch"—a parasite "so small that he is hardly visible" The discovery of the cause of this common disease seems of minor importance now, but it is of interest in medical history because, had Avenzoar's discovery been remembered a hundred years ago, "itch struck in" could hardly have been considered the cause of three-fourths of all diseases, as it was by the famous Hahnemann

The illustrious pupil of Avenzoar, Averrhoës, who died in 1198 A D, was the last of the great Arabian physicians who, by rational thinking, attempted to stem the flood of superstition that was overwhelming medicine. For a time he succeeded; but at last the Moslem theologians prevailed, and he was degraded and banished to a town inhabited only by the despised Jews.

To early Christians belongs the credit of having established the first charitable institutions for caring for the sick; but their efforts were soon eclipsed by both Eastern and Western Mohammedans. As early as the eighth century the Arabs had begun building hospitals, but the flourishing time of hospital building seems to have begun early in the tenth century. Lady Seidel, in 918 A D., opened a hospital at Bagdad endowed with an amount corresponding to about $1,500 a month. Other similar hospitals were erected in the years immediately following, and in 977 the Emir Adad-adaula established an enormous institution with a staff of twenty-four medical officers. The great physician Rhazes is said to have selected the site for one of these hospitals by hanging pieces of meat in various places about the city, selecting the site near the place at which putrefaction was slowest in making its appearance.

By the middle of the twelfth century there were about sixty medical institutions in Bagdad alone, and these were free to all patients and supported by official charity

The Emir Nureddin, about the year 1160, founded a great hospital at Damascus as a thank-offering for his victories over the Crusaders. This great institution completely overshadowed all the earlier Moslem hospitals in size and in the completeness of its equipment. It was furnished with facilities for teaching, and was conducted for several centuries in a lavish manner, regardless of expense. But little over a century after its foundation the fame of its methods of treatment led to the establishment of a larger and still more luxurious institution —the Mansuri hospital at Cairo. It seems that a certain sultan, having been cured by medicines from the Damascene hospital, determined to build one of his own at Cairo which should eclipse even the great Damascene institution.

In a single year (1283-1284) this hospital was begun and completed No efforts were spared in hurrying on *the good work, and no one was exempt from performing* labor on the building if he chanced to pass one of the adjoining streets It was the order of the sultan that any person passing near could be impressed into the work, and this order was carried out to the letter, noblemen and beggars alike being forced to lend a hand. Very naturally, the adjacent thoroughfares became unpopular and practically deserted, but still the holy work progressed rapidly and was shortly completed.

This immense structure is said to have contained four courts, each having a fountain in the center; lecture-halls, wards for isolating certain diseases, and a department that corresponded to the modern hospital's "out-patient" department. The yearly endowment amounted to something like the equivalent of $125,000. A novel feature was a hall where musicians played day and night, and another where story-tellers were employed, so that

persons troubled with insomnia were amused and melancholiacs cheered Those of a religious turn of mind could listen to readings of the Koran, conducted continuously by a staff of some fifty chaplains Each patient on leaving the hospital received some gold pieces, that he need not be obliged to attempt hard labor at once

In considering the astonishing tales of these sumptuous Arabian institutions, it should be borne in mind that our accounts of them are, for the most part, from Mohammedan sources Nevertheless, there can be little question that they were enormous institutions, far surpassing any similar institutions in western Europe The so-called hospitals in the West were, at this time, branches of monasteries under supervision of the monks, and did not compare favorably with the Arabian hospitals.

But while the medical science of the Mohammedans greatly overshadowed that of the Christians during this period, it did not completely obliterate it. About the year 1000 A.D. came into prominence the Christian medical school at Salerno, situated on the Italian coast, some thirty miles southeast of Naples Just how long this school had been in existence, or by whom it was founded, cannot be determined, but its period of greatest influence was the eleventh, twelfth, and thirteenth centuries. The members of this school gradually adopted Arabic medicine, making use of many drugs from the Arabic pharmacopœia, and this formed one of the stepping-stones to the introduction of Arabian medicine all through western Europe.

It was not the adoption of Arabian medicines, however, that has made the school at Salerno famous both in rime and prose, but rather the fact that women there practised the healing art. Greatest among them was Trotula, who lived in the eleventh century, and whose

learning is reputed to have equaled that of the greatest physicians of the day. She is accredited with a work on *Diseases of Women*, still extant, and many of her writings on general medical subjects were quoted through two succeeding centuries. If we may judge from these writings, she seemed to have had many excellent ideas as to the proper methods of treating diseases, but it is difficult to determine just which of the writings credited to her are in reality hers. Indeed, the uncertainty is even greater than this implies, for, according to some writers, "Trotula" is merely the title of a book. Such an authority as Malgaigne, however, believed that such a woman existed, and that the works accredited to her are authentic. The truth of the matter may perhaps never be fully established, but this at least is certain—the tradition in regard to Trotula could never have arisen had not women held a far different position among the Arabians of this period from that accorded them in contemporary Christendom.